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DESIGN AND OPERATING PARAMETERS FOR EMISSION CONTROL STUDIES: PHELPS DODGE, AJO, COPPER SMELTER

I. J. Weisenberg, et al

Pacific Environmental Services,
Incorporated

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DESIGN AND OPERATING PARAMETERS FOR EMISSION CONTROL STUDIES: PHELPS DODGE, AJO, COPPER SMELTER

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A. INTRODUCTION AND SUMMARY

The purpose of this report is to present background design data on the Phelps Dodge Corporation, New Cornelia Branch Smelter at Ajo, Arizona in sufficient detail to allow air pollution control system engineering studies to be conducted. These studies are primarily concerned with lean SO_2 streams that are currently not being captured.

Physical layout of the smelter and surrounding area along with existing smelter and control equipment is presented. Ductwork that would be considered for future system tie-in is defined. Emissions from operating equipment, gas flow rates, temperatures, sulfur balance and process flow sheet are included. Utilities, stack dimensions, footing requirements, and solid waste handling are defined. Available area for new control equipment, gas characteristic variation and potential new control equipment installation problems are discussed.

B. PLANT LOCATION, ACCESS AND OVERALL GENERAL ARRANGEMENT

The Phelps Dodge Corporation smelter is located adjacent to the town of Ajo, Arizona. An enlargement of the USGS map, showing land contours of the immediate area, is shown in Figure 1. Design altitude for the plant is 1800 ft. with plant site coordinates of latitude $32^{o}22'N$ and longitude $112^{o}52'W$.

Overall plant and smelter general arrangement are shown in Figure 2. The primary particulate emission sources are the crushing and screening operations and the reverberatory furnaces and converters. The primary sources of sulfur dioxide are the reverberatory furnaces and the converters.

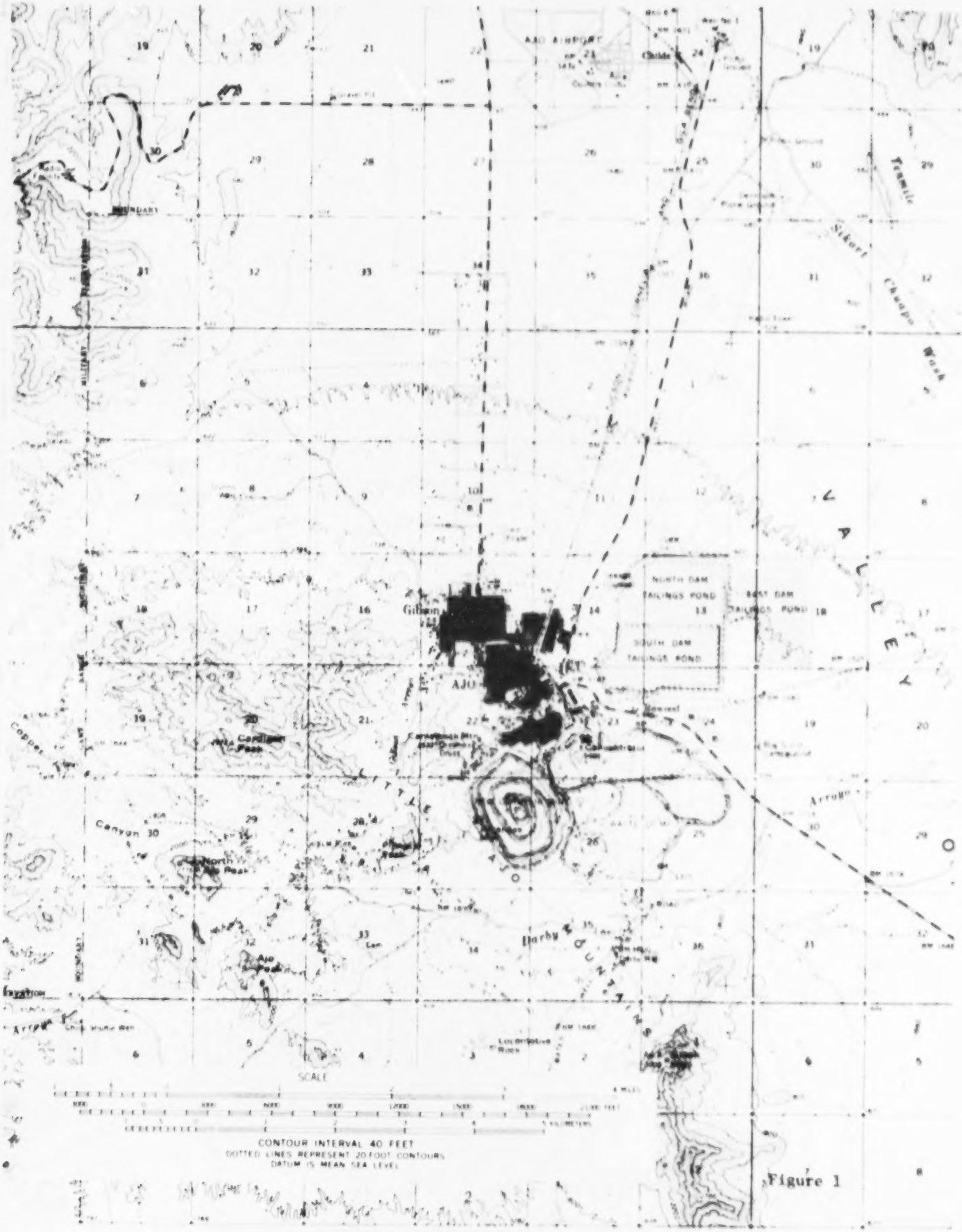
AJO AIRPORT
NORTH DAM
TAILINGS POND
EAST DAM
TAILINGS POND
SOUTH DAM
TAILINGS POND
AJO
Gibson
Ajo Cardiac Peak
Canyon 30
North Ajo Peak
Ajo Peak
Locomotive Rock
Tramway
Arroyo
SCALE
CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20 FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

Figure 1

Figure 2. GENERAL ARRANGEMENT DRAWING
(Located in Pocket Inside Back Cover)

The major equipment at the Phelps Dodge/Ajo smelter consists of one reverberatory furnace with waste heat boilers, three Peirce-Smith converters with waste heat boilers, one Great Falls oxidizing furnace, and an anode furnace with casting wheel. Major control equipment consists of an electrostatic precipitator for dust collection from the reverberatory furnace and converter gases along with a 600 TPD single contact acid plant and a DMA absorption plant for SO_2 control currently in the start-up phase. Reverberatory furnace gases after dust collection in the precipitator will be treated in the DMA absorption plant for SO_2 removal or discharged directly to the main stack. After dust collection in the precipitator the converter offgases are treated in either the single contact acid plant or the dimethylaniline (DMA) absorption plant.

C. PROCESS DESCRIPTION

Phelps Dodge Corporation operates an open pit copper ore mine, ore crushing, grinding, and milling equipment, flotation machines for ore concentrating, and copper smelting equipment at Ajo, Arizona. Only the copper smelting equipment and associated control equipment are described in this report. The process flow is shown schematically in Figure 3.

Concentrate, which contains copper together with sulfur, iron, and some insoluble material (primarily silica and alumina), is received from the concentrator and is loaded into containers, which are carried by overhead cranes to the charging stations at the reverberatory furnace.

Concentrate is charged into the reverberatory furnace through the sidewalls, with machines called slingers. The furnace is about 100 feet long, 30 feet wide and 11 feet high. Its main purpose is to melt the concentrate. This is done by firing the furnace with natural gas. In the furnace the melting concentrate makes a pool or bath about 4 feet deep. The lighter components of the bath rise to the

Process Flow and Sulfur Balance

Phelps Dodge Corp / Ajo Branch | prepared Oct, 1975

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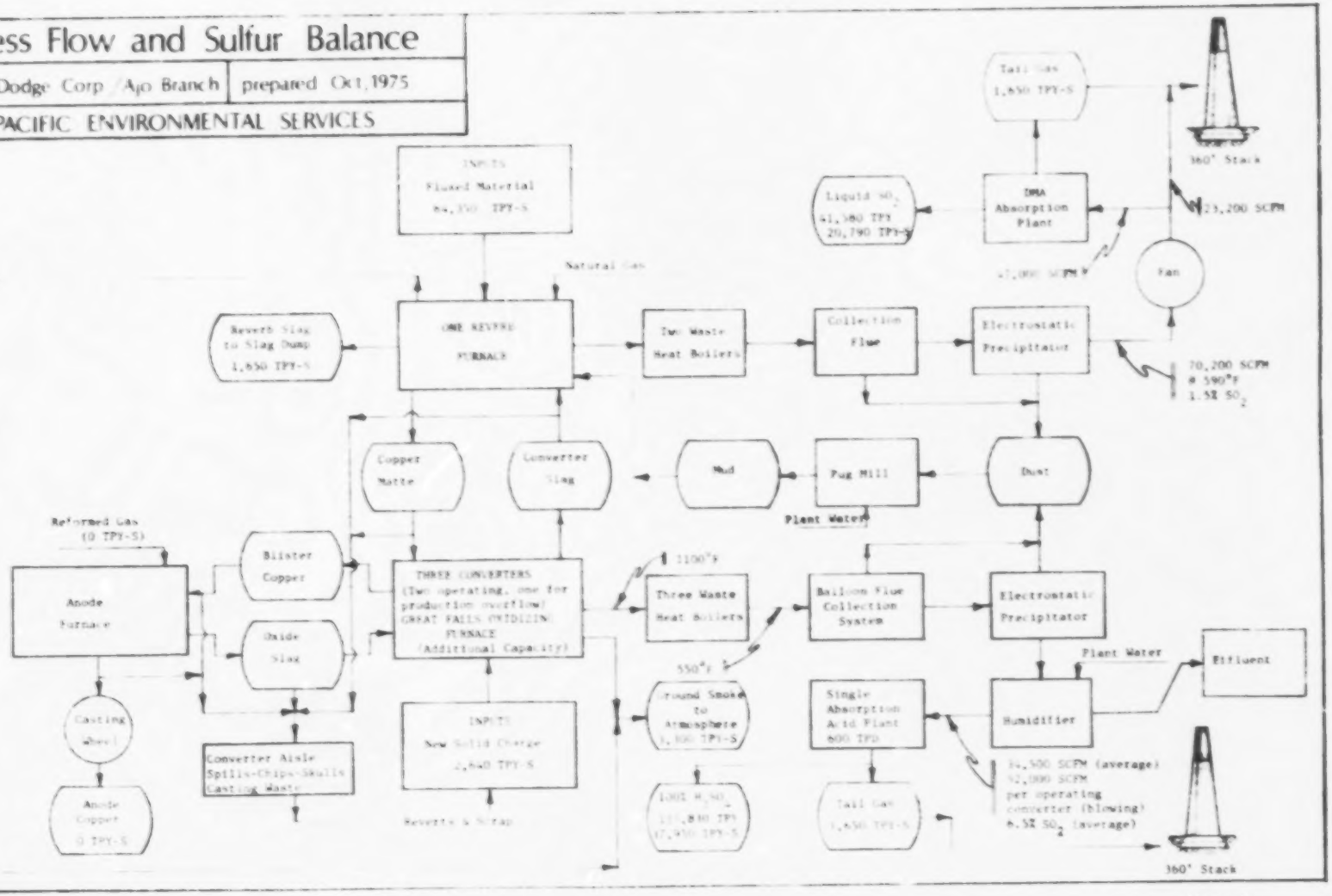

Figure 3.

top making a slag which is periodically skimmed off as a waste product. The heavier (copper-bearing) part of the bath sinks to the bottom and is withdrawn into ladles for further treatment. This product is composed almost entirely of copper, iron and sulfur, and is called "matte." As slag and matte are withdrawn from the furnace, more concentrate is added, and the melting process proceeds. Gases from the reverberatory furnace pass through a set of boilers, making steam for generating electricity, then through a precipitator to the gas treatment plant.

The ladles of matte taken from the reverberatory furnace are transported by overhead cranes to converting vessels. Air is blown through the liquid matte in the converters. Oxygen in the air unites with the sulfur, making sulfur dioxide gas which goes through a flue system to the gas treament plant. The iron in the matte is also oxidized, and when silica material is introduced into the converter, the iron oxide and silica combine to form a component in the matte which is lighter than the copper. This material rises to the surface to make slag, which is skimmed off and returned to the reverberatory furnace. This process is repeated until a charge (about 50 tons) of blister copper is left in the converter.

The blister copper, which contains a small amount of sulfur, is then poured into an oxidizing furnace. All the remaining sulfur is removed by blowing more air through the liquid copper, leaving a slight excess of oxygen. Now the copper is practically free of impurities.

The copper is then transferred to the anode furnace, where it is accumulated for a 24-hour period and then refined by blowing a reducing gas (reformed mixture of natural gas and air) through the molten charge. The carbon monoxide and hydrogen in the reducing gas unite with the oxygen in the copper, forming carbon dioxide and water which leave the furnace as gases. When nearly all of the oxygen has been eliminated, the copper is cast into 750-pound slabs called anodes.

The anodes are loaded on railroad flat cars and shipped to the Phelps Dodge refinery at El Paso, Texas. There they are put through the electrolytic process for further refining of the copper and recovery of the small amount of by-product gold and silver which has remained in the copper through the smelter.

D. EMITTING EQUIPMENT

a. Reverberatory Furnace (Reference 1).

A single reverberatory furnace, 30 feet wide and 100 feet long (inside dimensions), fired with seven 8-inch natural gas burners, processes concentrates from the milling and flotation plant. The concentrates, which comprise over 90% of the furnace charge, are received from the filter plants by conveyor and with an addition of limerock are placed in charge cans of 259 cu.ft. or approximately ten tons capacity. Each charge is weighed on the scales. When the can is filled and when required at the furnace, it is carried by overhead crane to a charge point above and to the side of the furnace. Six charge ports are provided, three on each side of the furnace. A concrete bin of approximately 1600 tons capacity is provided for surge storage of concentrates. When needed the concentrates are reclaimed by clamshell from the storage into the charge cans. The preparation department has a crushing plant containing a 36 x 48 jaw crusher and a 4-ft standard cone crusher.

The bath smelting furnace was designed for wet smelting. The crucible of the furnace is of rammed periclase in sections with water-cooled 20-ft high copper jackets on top of the crucible along the sides of the furnace and the working bottom of the furnace is magnetite fused in place. The bath smelting furnace requires reaction between the added new charge and the liquid bath to cause spreading of the new charge. In case of calcines, charging them through an inclined pipe imparts sufficient velocity that when they strike the liquid bath reaction starts immediately causing the necessary spreading.

This gravity charging method cannot be used with wet concentrates however, as they will not flow through an inclined pipe as calcines will do. Considerable research was necessary in developing proper charging equipment. The conditions found necessary were to be able to place the wet concentrates within the furnace at a considerable velocity and at a relatively flat angle so that the wet concentrates would penetrate the liquid bath sufficiently to start the spreading reaction, and the horizontal velocity being sufficient to prevent the concentrates from piling up in one place. A high speed belt slinger was developed which has been quite satisfactory. Six slingers are provided, three on each side of the furnace; each as a port through the sidewall, covered with a vertically movable door when not in use. When charging is to be done, the door is raised by an air cylinder, the slinger started, and concentrates dropped into the slinger from the charge can overehead. The slinger is adjustable as to angle of throw horizontally and vertically and as to speed of the belt. The rate of charge for a single slinger is 1.5 to 2 tons/min. The handling of the wet charge through cans transported by overhead crane, and the spreading of the charge by mechanical slingers has worked well and has permitted realizing the benefits of bath smelting with a raw charge. The loading of the furnace is done by one man and is controlled by visual inspection.

The Ajo furnace is constructed of sprung silica arch and the brickwork is maintained by silica slurry hot patching. The silicious material of over 90% SiO_2 is ground wet in a ball mill and pumped to a storage tank above the furnace, from which it is blown and sprayed on to the interior surface of the brickwork. A curtain damper has been used successfully in the Ajo furnace since starting and its use has resulted in better working conditions around the flues and boilers and has resulted in decreased maintenance expense in the uptake and flues to the boilers. The curtain damper sections are made of cast refractory supported by loops of water-cooled steel tubing and maintained by slurry patching.

When the doors along the side of the furnace are opened and the slinger started the pressure in the furnace tends to increase causing fugitive gases to leave the feed openings during the feeding process. The furnace normally tends to be below atmospheric pressure and operated in a reducing atmosphere. Approximately 1.0 to 1.5% SO_2 gas leaves the reverberatory furnace and is cooled in the waste heat boilers. There is one opening and launder for the slag leaving the reverberatory furnace and three for the matte. Fugitive emissions are generated during slag and matte tapping. The hole in the side of the furnace is plugged with clay material that is punched clear to open and resealed by placing a glob of clay on the end of a rod and forcing it into the hole.

There are hoods located above the matte launders. These hoods are some distance away from the opening to allow use of the hole punching machine which is moved along an overhead rail for placing in position at the three locations. Each hood can be closed off and when in use the system will pull 40,000 to 50,000 SCFM of air. Fugitive emissions are generated at these points but the prevailing winds tend to move them away from operating personnel. (Ref. 2).

b. Converters (Reference 1).

The three Peirce-Smith converters have 50 tuyeres each and have the riding rings on the ends of the shells. About one-half of the tuyeres are one and one-half inches and the rest are two inches. The converter flux is handled in charge cans similar to the ones used for handling furnace charge and are transported by the converter crane to a position above the end of the converter where the silica flux can be discharged into the Garr gun in the end of the converter. Blister copper is finished to only a light blister, no oxide slag being skimmed, and is transferred to the holding furnace equipped with tuyeres where the oxidation is completed. The use of this combination holding and oxidation furnace has resulted in decided economics as it has obviated making an oxide slag in the Peirce-Smith converter

with resulting excessive corrosion of the converter lining. The use of this holding furnace also results in increased life of the anode furnace lining as little or no oxidation is required in the anode furnace.

Generally the reverberatory furnace produces more matte than one Peirce-Smith converter can handle. The surge-storage capacity of the bath furnace makes it possible to accumulate excess matte and then two converters may be operated for one shift or more, getting rid of the excess. Jackets holding the tapping plates are water cooled and three tap holes are provided. The furnace is parallel to the conveter aisle and very short matte launders are used.

The converter hoods consist of a radiation cooled rib stainless steel door that is moved down over the converter opening to cover the forward portion. Tracks are located along the sides of the converter opening supporting the door. Below the track a very close fitting wall is formed. This wall is also ribbed for radiation cooling. The gap between the sides of the hood and the converter shell is approximately 2 to 3 inches. This gap is necessary because a tight seal cannot be held due to the differential expansion of the converter and the tendency for plugging resulting from material splash. The backside of the hood is sealed by a flap that is pressed against the back of the converter by two pneumatic cylinders. These cylinders allow the flap to be pulled back when the converter is rotated. The back flap is then reset for sealing after the converter is placed in its new position. They have also tried to put a partial hood over the top of the converter door where there is a wide gap (2 to 3 inches) and where (as noted in other smelters) some significant fugitive emissions are produced.

The design of this door and hood was obtained from Europe and is a simplification compared to the water cooled hoods used in some smelters. The rectangular rib design provides radiation cooling similar to the fins on an aircooled reciprocating engine cylinder. They have noted a considerable increase in radiation heat when ribs have been used compared to

previous hoods where there were no ribs. The hood is made entirely of stainless steel and is approximately 3/4 inches thick for both the flat plate portion and the rib. The door and walls are made of sections of large stainless steel castings. Steel cables are used to pull the door up and down along the track for positioning.

There are three 13' x 30' Peirce-Smith converters. They usually use two converters and the third is used as a production overflow. During those times when all three converters are used they have an additional Great Falls twelve foot diameter oxidizing furnace that is used to provide additional capacity. From the Great Falls converter the material is then taken to the thirteen by thirty foot anode furnace.

Operation of the converters takes approximately 8 hours total time for each complete process cycle. The converters will generate a peak SO_2 concentration of 6 to 7% and an average of 4.5 to 5% during the slag blow. The slag blow takes approximately 45 to 60 minutes and there are at least three sometimes four. The number of blows is judged by eye from the color of the gases leaving the converter mouth. The copper blow which takes two hours will peak at 14% SO_2 and average 8 to 9% (Ref. 2).

c. Other Emitting Equipment

In the design of the plant only one anode furnace was provided as it was thought that the second Peirce-Smith converter would be available to hold copper while the one anode vessel was in the refining and casting parts of the cycle. However, it was soon found that numerous delays resulted when it was necessary to blow two converters and also when one converter was down for repairs. A 12-ft Great Falls converter was transferred from the United Verde plant and set up between the converters and anode furnace and remodeled so that it could be used for a holding furnace and also for further oxidation of the copper. The vessel was lined with nine inches of basic brick, insulated from the shell. Four 2-in. tuyeres were provided and a gas burner installed in the cap which was turned 180^{o}

from its original position when used as a regular copper converter. The single anode furnace 13 x 30 ft was designed to handle the day's production of copper, about 200 tons average, making only one pour per day. The ends of the furnace are dished, and the lining is insulated from the shell throughout. In design of the casting wheel a great deal of attention was paid to the drive mechanism giving smooth operations with few rolled edges and little trimming required. Tuyeres have now been installed in the anode furnace and are used for reduction of the copper with reformed gas. In the past, reduction of the copper has been done with green oak poles.

Particulars are generated in the mining and millings operations at Ajo. Leaks in ducts and other pieces of equipment cause fugitive emissions of particulate and SO_2. Ladles holding matte and slag produce visible fugitive emissions.

It is reported that 15% (ground smoke) is generated throughout the plant (Ref. 2). This was interpreted to mean 15% of the SO_2 generated is fugitive emissions.

E. EXISTING CONTROL EQUIPMENT

Reverberatory furnace offgases and converter offgases are treated in separate electrostatic precipitators.

The reverberatory furnace electrostatic precipitator consists of two independent horizontal parallel units to handle 150,000 ACFM (600°F and 13.8 psia). Average grain loading is in the range of 0.9 Gr/SCF (32°F and 14.7 psia). Gas treatment time is 5.97 seconds; pressure drop across the precipitator is 0.5 inches w.c. maximum. Collecting surfaces are plates; the discharge electrodes are spring steel wires. The transformer- rectifiers are silicon full wave for 45KV (DC) average; there is an automatic voltage control system to maintain the optimum precipitator operating efficiency (about 96% neglecting sulfates). Dust collected is conveyed to a storage bin from which it is pneumatically conveyed to the charge mixing area for the reverberatory furnace by a fluidflow automatic pump. This pump can handle 20,000 pounds per

hour when supplied with 280 SCFM compressed air at 30 psig.(Reference 3).

The converter electrostatic precipitator is similar to the one for the reverberatory furnace. There are two independent horizontal parallel units with three fields each to handle 210,000 ACFM (650°F and 13.8 psia). Average grain loading is on the order of 1.3 Gr./SCF (32°F and 14.7 psia). Gas treatment time is 6.4 seconds; pressure drop across the precipitator is 0.5 inches w.c. maximum. Optimum precipitator operating efficiency is about 97.2% neglecting sulfates. Total collecting surface area is 29,808 sq. ft. Dust collected is conveyed to a storage bin from which it is loaded into a truck for haulage to the crushing plant receiving hopper and used with the converter flux mix. To keep the precipitators above the condensation point of the residual gases whenever gases are not being treated in the gas treatment plant there are burners near the precipitator entrance which can be fired with natural gas or diesel oil. Combustion products are exhausted by two exhaust fans (one for each precipitator outlet duct). (Reference 3).

The gas treatment plant consists of a sulfuric acid plant and a sulfur dioxide absorption plant. The former is designed to produce 600 tons of acid per day, and the latter can produce approximately 50 tons of liquid sulfur dioxide per day. The sulfur dioxide from the converters can be routed to either plant to make sulfuric acid or liquid sulfur dioxide, but the gas from the reverberatory furnace, which is too dilute to be treated in the sulfuric acid plant, flows only to the absorption plant. The purpose of both plants is to eliminate sulfur dioxide from the offgases generated by the smelting operation.

The hot sulfur dioxide gas from the converters, containing dust particles, passes through gas coolers where its temperature is lowered to approximately 600°F, and some of the dust particles are removed. The heat removed from the gas generates steam for subsequent uses. The gas then passes through an electrostatic precipitator, where the majority of the dust is recovered, and then on to

the gas scrubbing section of the sulfuric acid plant. The scrubbing section consists of a humidifying tower, a cooling tower, and a mist precipitator. The first two towers cool the gases further and remove the remaining dust particles. The mist precipitator is designed to remove the sulfuric acid mists from the gas stream to avoid corrosion of equipment down stream. From the mist precipitator the gas passes through a drying tower, where moisture is removed. The sulfur dioxide gas then passes through two blowers into the shell side of a series of heat exchangers, where it is heated by hot sulfur trioxide gas, and then passes on to a catalyst chamber. Sulfur dioxide gas is converted to sulfur trioxide in the catalyst chamber at an elevated temperature. The sulfur trioxide gas passes through the tube side of the heat exchangers and loses much of its heat before entering the absorbing tower. The circulating acid in the absorbing tower absorbs the incoming sulfur trioxide. Sulfuric acid is produced during the process of absorption. Additional water is required at times to maintain a desired acid strength. The acid is pumped to storage, whence it is shipped by railroad cars or tank trucks to purchasers.

The single absorption 600 ton per day Monsanto Envirochem sulfuric acid plant can operate from approximately 1.5% to as high as 14% SO_2 stream. The lower value requires continuous preheat to the SO_2 to SO_3 converter and if sustained for a long time period will result in a water balance problem, with consequent reduction in acid strength. The higher value is limited by the cooling capacity of the gas heat exchangers on the inner stages of the converter. Typically, a 6.5% SO_2 stream is treated.

Many problems have been encountered with operation of the acid plant. It was started up in the middle of November 1972 and still has not proven satisfactory (Ref. 2). The following problems were encountered:

1. Insufficient mist precipitator capacity.
2. Extensive corrosion of the acid heat exchanger.
3. Erosion of the dome of the humidifier chamber. The humidifier chamber is essentially a spray cooler.

It was determined that fluorine was in the water in sufficient quantities to cause some erosion.

4. Continuous problems with pumps, lines and coolers in terms of corrosion and even original design capabilities were encountered.

The sulfur dioxide absorption plant (DMA) was built to supplement the acid plant with additional sulfur dioxide gas. Reverberatory gas entering the absorption plant is first cleaned by an electrostatic precipitator and gas scrubbers then absorbed by the dimethylaniline (DMA) solution. The gas is then dried by sulfuric acid, and is compressed and condensed to a liquid form. Liquid sulfur dioxide is stored under pressure and is vaporized to supplement the acid plant operation whenever necessary.

The DMA plant also encountered many practical problems such as:

1. The blower motor bearing went out very rapidly.
2. The FRP main duct collapsed because it originally did not have sufficient ring supports installed.
3. The SO_2 compressor failed because of particles entering the stream.
4. The drying tower was not designed properly to give uniform flow of gas and liquid.
5. Extensive corrosion in the weak acid system.
6. Design of the SO_2 vaporizor was also not satisfactory. Considerable corrosion was encountered and is believed caused by not having a drain in the system.

With the DMA system collecting part of the gases of the reverberatory furnace and with the close fitting hoods on the converters and the sulfuric acid plant it is believed that over 90% (92%) of the input sulfur can be fixed with the system presently installed after modification to eliminate the problems recently encountered.

A nearby paper plant is a potential customer to receive the liquid SO_2 production from this smelter.

Three recently prepared papers by plant personnel describe in detail the gas treatment facilities, the SO_2 absorption plant and the use of waste heat boilers in the converter department, (Ref. 3, 4, 5). Copies of these papers are included for reference in the Appendix.

F. GAS SYSTEM DUCTWORK

The following gas system ductwork description was taken from Reference 3.

Gases from the reverberatory furnace are passed through two parallel waste heat boilers to partially cool the gases and to recover some of the heat value which can be used for the production of electricity or for the production of the low pressure air required for copper converting. The gases are then treated in an electrostatic precipitator, Figure 4. Where the two uptake flues from the waste heat boilers joined the balloon flue for the reverberatory furnace gases, flue modifications were made so that the gases could continue either to enter the balloon flue or to bypass the balloon flue and be sent to a plenum chamber for mixing and then to a new electrostatic precipitator unit. Remotely controlled dampers in the flues accomplish this gas path selection.

An induced draft fan was installed to draw the reverberatory gases from the reverberatory furnace through the waste heat boilers, the flue system and the electrostatic precipitator. This fan can handle 150,000 ACFM @ 600°F with a suction of -1.75" H_2O and a discharge of 3.25"H_2O. All of the gases can be discharged to the 360 foot concrete stack through a duct which enters the breeching flue between the old Cottrell plant and the stack, or part of the gases can go to the stack and part to the SO_2 absorption plant. A remotely controlled damper in the flue going to the stack controls the total volume of gas removed from the reverberatory furnace and the distribution of the gas.

Treatment of this low SO_2 content (1.5-2%) gas that is not sent to the main stack is in the SO_2 absorption plant, described in a previous section.

FIGURE 4

REVERB. ELECTROSTATIC PRECIPITATORS - GENERAL ARRANGEMENT
ELEVATION LOOKING WEST

(Located in Pocket Inside Back Cover)

Formerly, gases from the two Peirce-Smith converters were diluted and partially cooled by allowing large quantities of air to enter the flue system at the converter hoods. This practice required change because the gases must be kept above 4% SO_2 for efficient acid plant operations. The converter blowing operations were reviewed to determine the best approach for the new conditions.

A third converter was installed to improve the availability of converters for more constant production of gases by the converters while they are converting matte. The mode of operation was to blow one converter on "A" shift, two converters on "B" shift, and one converter on "C" shift. The former mechanical punchers (26 - 3" tuyeres) were replaced with Gaspe mechanical punchers (52 - 1 3/4" tuyeres); the new converter has a Gaspe puncher.

The hoods and the old balloon flue system behind the two old converters were removed. In order to reduce air infiltration to no more than 100% a hood that would fit as tightly as possible over the converter mouth was designed, Figure 5. The hood sidewalls approach within 2 to 3 inches of the converter apron; further approach would allow splashing material to seal the opening and restrict movement of the converter. Since a high infiltration of air no longer is available to cool the gases, a stainless steel hood which provides for convection was selected. This hood starts at the converter mouth and ends 13 feet from the centerline of the converter. At that point a mild steel flue section connects the hood castings and the waste heat boiler.

The movable roof section for the hood travels on rails; when it reaches its bottom level of travel, there is a dip in the rails so that the hood drops to make a tight seal along its top and sides. The lower edge is then only a few inches from the converter apron. To seal the lower, rear opening of the hood there is a large spark shield casting which can be positioned by air cylinders to fit against the converter apron. The movable roof section is positioned by means of cables, a hoist and a counterweight.

FIGURE 5

CONVERTER AISLE
SECTIONAL ELEVATIONS LOOKING NORTH

(Located in Pocket Inside Back Cover)

In order to capture any smoke that might escape from the converter hood an experimental exhaust hood was installed over the No. 3 converter hood. This installation included a fixed section and a movable section. However, the latter was eliminated after the positioning cable system caused operating problems. Design for the No.1 and No. 2 converters provides for longer fixed hood sections (these must not be too low or they will be easily damaged when charging matte or "pulling the converter collar"). Exhaust from the existing hood is by two 42" diameter vane axial fans each capable of exhausting 44,470 CFM. The fans operate at 1,640 RPM. A 50 HP motor is used to drive the fans with V-belts. For the experimental unit the gases are discharged to the atmosphere. Gases discharged from these fans and from the ones for the Nos. 1 and 2 converters enter ducts which take them to the base of the 360 foot concrete stack for mixing with other gases.

It is necessary to further cool the gases (after about 100% air infiltration at the converter mouth and after convertion cooling from the hood castings) so that standard steels can be used for the flues and to permit the use of a standard electrostatic precipitator. To do this waste heat boilers suitable for operation with copper converters were installed.

At the exit of each waste heat boiler there is a drop gate for use as a tight shut off for repairs and then a plug damper at the entrance to the balloon flue. The plug damper flue section is 6'-7" I.D. The plug damper travel is 1'-5½". This damper controls the flow of gases from the converter and waste heat boiler to the balloon flue.

A new balloon flue was constructed to accommodate the gases as they leave the three waste heat boilers. This flue is 175 feet long before it turns to run another 36 feet and joins the old balloon flue which goes to the old Cottrell plant. At the point where the old and new balloon flues join there is a damper which is used to control flow of gases to the old system. The balloon flue height is 19'-1" above the drag chain box and the radius of the top section is 5'-9". There are three expansion joints (sliding plates covered with rockwool and then with Cohr lastic

coated fabric). The drag chain system is operated automatically.

The distance between the balloon flue openings for the No. 1 and No. 2 converters is 66'-0"; the opening for the No. 2 is 48'-3" north of that for No. 2. Gases flow from the top of the balloon flue through two short flues to the converter electrostatic precipitator. These flues are 10'-7" south of and north of the centerline of the No. 2 balloon flue entrance.

After the gases leave the precipitators, they pass through 6 foot diameter ducts and are controlled by dampers so that all of the converter gases can go to the acid plant or all to the SO_2 absorption plant or part of the gases to each plant. At this point the converter gas contains some dust, acid mist, water vapor, and other impurities. Further gas purification steps consist of gas scrubbing, gas cooling, and acid mist removal. Treatment of the gases in the SO_2 absorption plant and the acid plant is discussed in an earlier section of the report.

G. SULFUR BALANCE AND GAS COMPOSITION AT SYSTEM EXIT

The principal sulfide minerals in the concentrates are chalcopyrite and bornite with a variable amount of pyrite. The grade of the matte is always over 30% but with judicious use of high quartz ore in the flux all reverts plus some concentrates are smelted in the converters. Control of magnetite is done by keeping the silica content of the converter slag 29-30% and by control of the matte and slag temperatures. Concentrates, as received from the filter plant, are given an addition of limerock and charged directly into the furnace by means of the slingers. Sufficient limerock is added to the charge to give 4.0 to 5.0% CaO in the final slag.

A typical concentrate analysis is as follows: (Ref. 1.)

Cu	S_iO_2	Al_2O_3	Fe	S	CaO	H_2O
30.43	8.0	2.4	27.2	31.0	0.7	7.28

Reverberatory Furnace Feed	Dry Tons
Concentrates	19,638
Limerock	925
Reverts	196
Total	20,804

	Tons	Cu	Fe	S
Matte produced	16,704	37.71	34.0	25.5

An average sulfur balance for the Phelps Dodge Ajo smelter is presented in Table 1. Of the 203 tons per day of sulfur, approximately 183 tons per day are captured. The acid plant and DMA plant capture 178 tons per day and 5 tons per day are contained in the slag and solid wastes disposed of in the dump. With these figures as a basis, the overall smelter control efficiency is 90.1%. An average of 10 tons per day of sulfur (20 tons per day of SO_2) are discharged from the stack and fugitive emissions account for an additional 10 tons per day of sulfur lost to the atmosphere.

The volumetric gas flow at the converter electrostatic precipitator caries from 64,100 ACFM at 540°F to 73,100 ACFM at 515°F. The tuyeres deliver about 26,000 SCFM of air to the converters and this is further diluted with another 26,000 SCFM. The acid plant is capable of handling 52,000 SCFM.

Table 2 presents typical gas stream characteristics reported by Phelps Dodge Corporation (Ref. 6).

Table 1. PHELPS DODGE CORPORATION AJO, ARIZONA

Average Sulfur Balance Summary

Sulfur Input	Roaster		Reverb		Converter		Slag & Solid Waste	Fugitive Emissions	Present Sulfur Captured	Stack Emissions
TPD-S	$\%SO_2$	TPD-S	$\%SO_2$	TPD-S	$\%SO_2$	TPD-S	TPD-S	TPD-S	TPD-S	TPD-S
203	-	-	1.5	68	5.4	120	5	10	183	10

TABLE 2

GAS STREAM CHARACTERISTICS
OF
PHELPS DODGE CORPORATION
AJO COPPER SMELTER

SO_2 Source		Flow rate	Concentration Percent			Particulate		Disposition of Gas Stream			Product Disposition		Plant Age	Difficulty of Retro-fitting	Remarks
Weak	Strong	Scfm @ 70°F 14.7Psi	SO_2	SO_3	O_2	Treatment	Outlet Loading	Plant	Type	Capacity TPD	Used	Sold		Control	
							Gr/ACF								
Reverb.		45-55,000	1-3	0.1	5	Electro. Precipit.	.06 gr	DMA			X		1950		Control units installed undergoing modifications
						Scrubber	Nil								
	Conv.	0-78,000	4-0	0.1	8-12	Precipit.	.09 gr	Acid	Single Absorption	750		X			
						Scrubber	Nil								
								Emitted through stack							

Note: The plant generates its own power from waste heat and direct fired boilers. Water supply is limited. Uniform smelting charge characteristics.

Reference 6.

The following data were obtained from Reference 2.

Converter Offgas Composition*

Component	% b.v.
N_2	80
O_2	11
SO_2	6.9 - 9.8
SO_3	.05 - .07
Dust	.15 g/SCF Max

*27643 SCFM to 39,849 SCFM (32°F, 14.7 psia)

Converter Dust Composition

Component	% b.v.
Cu	19.0
Fe	17.0
Pb	0.83
Bi	0.61
F	Nil
Sb	Nil
As	0.39
Se	0.21
Si	15.0
Mg	0.57
Mo	0.08
Al	3.60
O_2	21.0
Cl	Nil

Converter Dust Particle Size Distribution

Mesh	
-48 + 65	0.5
-65 + 100	1.5
-100 + 150	2.5

Mesh (cont)	
-150 + 200	3.5
-200 + 270	5.0
-270 + 325	5.0
-325 + 32 Micron	16.6
-32 + 25 Micron	55.6
-25 Micron	9.8
	100.0

H. GAS CHARACTERISTIC VARIATION

It can be expected that SO_2 concentration in the offgas from the reverberatory furnace will vary significantly with time. This results from the variation in time required for decomposition or reaction of the various sulfide ores charged the furnace. This variation in SO_2 content has been known to vary as much as 10 to 1 within a given charging time cycle. While no data are yet available from this smelter concern this point, it should be considered for control system design.

SO_2 concentration in converter offgases will also vary considerably for an entirely different reason. The operation of the converters includes several, usually three, slag blows and one copper blow. Between these blows the hood above the converter is closed off by dampers so that the gases do not pass through the collection system to the acid plant. The attempt is always made to maintain at least one converter blowing gases into the system at any given time. Usually a converter will be provided with 20,000 SCFM to the tuyeres. An additional 100% of dilution air is estimated to be added to this gas flow resulting in a total gas flow from each converter in the range of 30,000 SCFM.

When a converter is blowing these will usually be approximately 30,000 SCFM at an SO_2 content in the range of 4.0 to 6.0%.

Because of the normal fluctuation in converter feed and operation, the SO_2 concentration can vary over a relatively wide range. In addition, the gas volume flow from the converter line to the acid plant can vary over a wide range from maximum to zero. Operation of the control system must be conducted in a manner to compensate to be typical providing satisfactory control.

I. STACK DESCRIPTION

A single 360 foot stack serves the emitting equipment at this smelter.

Main Stack	
Height	360 feet
Diameter (ID)	24 feet bottom
	15 feet top

J. PRESENT TECHNIQUE FOR SOLID WASTE HANDLING

Reverberatory furnace slag is hauled in slag cars to the slag dump. Converter slag is returned to the reverberatory furnace. Dust collected in the precipitators is transported by a pneumatic dust handling system to a pug mill and processed for charging to the reverberatory furnace.

K. FOOTING AND STRUCTURAL REQUIREMENTS

No local codes apply. The National Uniform Building Code is used. Seismic zone 2 and a wind load of 20 PSF are used for design. A snow load design value of 4PSF is standard for this smelter. The ambient temperature ranges from a minimum of $17^{\circ}F$ to a maximum of $120^{\circ}F$. The average wet bulb temperature is $75^{\circ}F$.

L. EXISTING AND POTENTIALLY AVAILABLE UTILITIES

Water supply is limited at the Ajo smelter. It is expected that future natural gas supplies will be limited. The availability of electricity is not known.

M. POTENTIAL NEW CONTROL EQUIPMENT INSTALLATION PROBLEMS

Available space for new control equipment can be found north of the existing reverberatory furnace or converters. No additional installation problems are apparent at this time.

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3. "Gas Treatment Facilities at the New Cornelia Branch of Phelps Dodge Corporation, Ajo, Arizona." Forrest R. Rickard, April 26, 1974.

4. "SO_2 Absorption Plant at the New Cornelia Branch of Phelps Dodge Corporation, Ajo, Arizona." W.J. Chen, April 26, 1974.

5. "Use of the Gas Coolers (Waste Heat Boilers) in the Converter Department at the New Cornelia Branch of the Phelps Dodge Corporation, Ajo, Arizona" James B. McBiles, April 26, 1974.

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A P P E N D I X

GAS TREATMENT FACILITIES AT THE NEW CORNELIA BRANCH OF PHELPS DODGE CORPORATION, AJO, ARIZONA

Forrest R. Rickard
Smelter Superintendent

The Ajo Smelter of the Phelps Dodge Corporation was placed in operation in 1950. Gases from the one Reverberatory furnace and from the two 13' x 30' Peirce-Smith converters were confined to separate balloon flues up to the entrance to the Cottrell Plant. There the gases mixed and passed through a pipe type Cottrell unit for removal of particulate matter. The gases then entered a 360 foot concrete stack for dispersal to the atmosphere.

Air quality control laws, formulated by the Federal and State governing bodies have made it necessary to prepare to be in compliance with the standards for particulate matter and for sulfur emissions. These have dictated changes in modes of operation and in facilities at the Ajo Smelter.

Since there are no overall accepted standard methods from which to choose, Ajo selected both a metallurgical gas acid plant and an SO_2 Absorption Plant together with gas handling and cleaning system changes. We are in compliance with the standards for particulate matter. We expect to achieve compliance with Arizona's sulfur emission limitations within the time limits prescribed by state law. As yet there are no federal sulfur emission limitations.

REVERBERATORY FURNACE GASES

Gases from the Reverberatory furnace have always passed through two (2) waste heat boilers (in parallel) to partially cool the gases and to recover some of the heat value which can be used for the production of electricity or for the production of the low pressure air required for copper converting. Therefore, these gases are suitable for treatment in a modern electrostatic precipitator. Where the two (2) uptake flues from the two (2) waste heat boilers joined the balloon flue for the Reverberatory gases, flue modifications were made so that the gases could continue either to enter the balloon flue or to bypass the

balloon flue and be sent to a plenum chamber for mixing and then to a new electrostatic precipitator unit. Remotely controlled dampers in the flues accomplish this gas path selection.

The electrostatic precipitator consists of two (2) independent horizontal parallel units to handle 150,000 ACFM (600°F and 13.8 psia). Average grain loading is in the range of 0.9 Gr/SCF(32°F and 14.7 psia). Gas treatment time is 5.97 seconds; pressure drop across the precipitator is 0.5 inches W.G. maximum. Collecting surfaces are plates; the discharge electrodes are spring steel wires. The transformer-rectifiers are silicon full wave for 45KV (DC) average; there is an automatic voltage control system to maintain the optimum precipitator operating efficiency (about 96%). Dust collected is conveyed to a storage bin from which it is pneumatically conveyed to the charge mixing area for the Reverberatory furnace by a fluidflow automatic pump. This pump can handle 20,000 pounds per hour when supplied with 280 SCFM compressed air at 30 psig.

An induced draft fan was installed to draw the reverberatory gases from the reverberatory furnace through the waste heat boilers, the flue system and the electrostatic precipitator. This fan will handle 150,000 ACFM @ 600°F with a suction of -1.75" H_2O and a discharge of 3.25" H_2O. All of the gases can be discharged to the 360 foot concrete stack through a duct which enters the breeching flue between the old Cottrell Plant and the stack, or part of the gases can go to the stack and part to the SO_2 Absorption Plant. A remotely controlled damper in the flue going to the stack controls the total volume of gas removed from the reverberatory furnace and the distribution of the gas.

Treatment of this low SO_2 content (1.5-2%) gas that is not sent to the stack is in the SO_2 Absorption Plant, discussed in another paper.

CONVERTER GASES

Formerly, gases from the two (2) Peirce-Smith converters were diluted and partially cooled by allowing large quantities of air to enter the flue system at

the converter hoods. This concept required change because the gases must be kept above 4% SO_2 for efficient Acid Plant operations. The converter blowing operations were reviewed to determine the best approach for the new conditions.

A third converter was installed to improve the availability of converters for more constant production of gases by the converters while they are converting matte. The mode of operation was to blow one converter on "A" shift, two converters on "B" shift, and one converter on "C" shift. The former mechanical punchers (26 - 3" tuyeres) were replaced with Gaspe mechanical punchers (52 - 1 3/4" tuyeres); the new converter has a Gaspe puncher.

The hoods and the old balloon flue system behind the two old converters were removed. In order to reduce air infiltration to no more than 100% a hood that would fit as tightly as possible over the converter mouth was designed. The hood sidewalls approach within 2 to 3 inches of the converter apron; further approach would allow splashing material to seal the opening and restrict movement of the converter. Since a high infiltration of air no longer is available to cool the gases, a stainless steel hood which provides for convection cooling was selected. This hood starts at the converter mouth and ends 13 feet from the centerline of the converter. At that point a mild steel flue section connects the hood castings and the waste heat boiler. Three grades of stainless steel castings are used:

Cast 28-4 Alloy (HC) for the side castings:
C 0.50 max.; Mn 1.00 max.; Si 2.00 max.; P 0.04 max.; S 0.04 max.; Cr 26.0-30.0; Ni 4.00 max.; Mo 0.50 max.

Cast 20-9 Alloy (HE) for roof and for movable section castings:
C 0.20-60; Mn 2.00 max.; Si 2.00 max.; P 0.04 max.; S 0.04 max.; Cr 26.0-30.0; Ni 8.0-11.0; Mo 0.50 max.

Cast 25-12 Alloy (HH) was found more suitable than HE for the roof and movable section casting and will be used for replacement castings:
C 0.20-0.50; Mn 2.00 max.; Si 2.00 max.; P 0.04 max.; S 0.04 max.; Cr 24.0-28.0; Ni 11.0-14.0; Mo 0.50 max.

Multiple castings were used for the original installation. However, casting and operating experience have shown that fewer castings are more desirable. The pattern can be called "waffle". The "waffle" areas are mostly 12" x 12" center to center of walls; other areas may be 7" x 9½", 7" x 10¼", 12" x 10¼", depending on their location on the casting. Interior ribs are generally 3/4" thick; exterior ribs are generally 1" thick. The castings are 1" thick on the surface presented to the gases. The "waffles" are 7" deep. The castings for one converter weigh about 109,760 pounds.

The movable roof section for the hood travels on rails; when it reaches its bottom level of travel, there is a dip in the rails so that the hood drops to make a tight seal along its top and sides. The lower edge is then only a few inches from the converter apron. To seal the lower, rear opening of the hood there is a large spark shield casting which can be positioned by air cylinders to fit against the converter apron. The movable roof section is positioned by means of cables, a hoist and a counterweight.

In order to capture any smoke that might escape from the converter hood an experimental exhaust hood was installed over the No. 3 Converter hood. This installation included a fixed section and a movable section. However, the latter was eliminated after the positioning cable system caused operating problems. Design for the No. 1 and No. 2 Converters provides for longer fixed hood sections (these must not be too low or they will be easily damaged when charging matte or "pulling the converter collar"). Exhaust from the existing hood is by two 42" diameter vane axial fans each capable of exhausting 44,470 CFM. The fans operate at 1,640 RPM; a 50 HP motor is used to drive the fans with V-belts. Bearing selection for the operating temperature proved to be incorrect. For the experimental unit the gases are discharged to the atmosphere. Gases discharged from these fans and from the ones for the Nos. 1 and

2 Converters will enter ducts which will take them to the base of the 360 foot concrete stack for mixing with other gases.

It is necessary to further cool the gases (after about 100% air infiltration at the converter mouth and after convection cooling from the hood castings) so that standard steels can be used for the flues and to permit the use of a standard electrostatic precipitator. To do this waste heat boilers suitable for operation with copper converters were installed.

At the exit of each waste heat boiler (one for each converter) there is a drop gate (for use as a tight shut off for repairs) and then a plug damper at the entrance to the balloon flue. The plug damper flue section is 6'-7" I.D. The plug damper travel is 1'-5½" (the positioner is outside the balloon flue; the rod for the plug damper passes through the balloon flue; a sleeve upstream of the plug damper supports that end of the plug damper rod). This damper controls the flow of gases from the converter and waste heat boiler to the balloon flue.

A new balloon flue was constructed to accommodate the gases as they leave the three waste heat boilers. This flue is 175 feet long before it turns to run another 36 feet and joins the old balloon flue which goes to the old Cottrell Plant. At this point (where the old and new balloon flues join) there is a damper which is used to control flow of gases to the old system. The balloon flue height is 19'-1" above the drag chain box; the radius of the top section is 5'-9". There are three expansion joints (sliding plates covered with rockwool and then with Fiberglastic coated fabric). The drag chain is a #104, heat treated steel drag chain with 6" pitch. The drag chain system is operated automatically.

The distance between the balloon flue openings for the No. 1 and No. 2 Converters is 66'-0"; the opening for the No. 2 is 48'-3" north of that for No. 2. Gases flow from the top of the balloon flue through two short flues to

the converter electrostatic precipitator. These flues are 10'-7" south of and north of the centerline of the No. 2 balloon flue entrance.

CONVERTER GAS CLEANING

The Converter electrostatic precipitator is similar to the one for the Reverberatory furnace. There are two (2) independent horizontal parallel units with three fields each to handle 210,000 ACFM (650°F and 13.8 psia). Average grain loading is on the order of 1.3 Gr./SCF (32°F and 14.7 psia). Gas treatment time is 6.4 seconds; pressure drop across the precipitator is 0.5 inches W.G. maximum. Optimum precipitator operating efficiency is about 97.2%. Total collecting surface area is 29,808 sq. ft. Dust collected is conveyed to a storage bin from which it is loaded into a truck for haulage to the crushing plant receiving hopper and used with the converter flux mix. To keep the precipitators above the condensation point of the residual gases whenever gases are not being treated in the Gas Treatment Plant there are burners near the precipitator entrance which can be fired with natural gas or diesel oil. Combustion products are exhausted by two exhaust fans (one for each precipitator outlet duct).

After the gases leave the precipitators, they pass through 6 foot diameter ducts and are controlled by dampers so that all of the converter gases can go to the Acid Plant or all to the SO_2 Absorption Plant or part of the gases to each plant. Treatment of the gases in the SO_2 Absorption Plant is discussed in a separate paper. This paper will discuss the treatment of converter gases in the Acid Plant.

At this point the converter gas contains some dust, acid mist, water vapor, and other impurities. Further gas purification steps consist of gas scrubbing, gas cooling, and acid mist removal.

The humidifying tower is a vertical, lead and acid brick lined steel tank 13'-11" I.D. shell by approximately 18'-0" high side walls. There is a

stainless steel section containing impingement trays and weak acid sprays which is mounted on top of the tower (this section is to be replaced because the materials of construction are not proper for this application). The bottom of the tower serves as a pump tank for the weak acid circulating stream. The gas (approximately 550°F and 13.6 - 13.7 psia) flows upward through the open-type humidifying tower through a spray of weak acid. Most of the heavy dust particles are scrubbed from the gas which is cooled by evaporation of the water from the weak acid. The weak acid is recirculated without cooling. A horizontal, centrifugal, corrosion resistant (wetted parts are of Alloy 20 or equal) pump whose capacity is 1400 gpm is used for this application. Approximately 13 gpm of waste weak acid is purged from the humidifying tower system to the Concentrator tailing launder. This purge contains about 1% solids and 7% H_2SO_4.

The gas then passes through a gas cooling tower. Cooling is achieved by running cooled, weak acid over a packed tower. The weak acid is cooled by water in shell and tube heat exchangers. Water and solid impurities removed from the gas stream are purged from the tower as a weak, impure acid. This effluent flows by gravity to the humidifying tower. The gas cooling tower is a vertical, lead and acid brick lined steel tank 14'-11" I.D. shell by approximately 31'-6" high side walls. The tower is packed with 3" polypropylene Intalox saddles; weak acid is distributed over these saddles. The bottom of the tower serves as a pump tank for the weak acid stream. This pump is similar to that for the humidifying tower. The heat exchangers are horizontal ones with impervious graphite tubes designed to cool the acid going to the gas cooling tower to 90°F with cooling water supplied at 81°F.

The process gas next flows through a lead and lead-lined steel electrostatic precipitator for removal of sulfuric acid mist and those solids not previously removed. The collection system consists of 284 vertical lead tubes

(all are 10" I.D., except eight which are 13" I.D.) fabricated with 10 lb. lead. In the center of each 10" tube there is a discharge electrode system consisting of a steel wire covered with star shaped lead and held taut by lead weights at the lower end. A water spray system is installed at the top of the precipitator for cleaning the electrodes. The gases pass through the tubes; an electrical charge is imparted on the particle of acid mist or solid; the particle is deposited on the electrically grounded collecting tube. The acid mist collected serves to wash the collected solids to the bottom chamber of the precipitator. This effluent flows to the humidifying tower system.

Main ducts in the purification system are of fiberglass reinforced polyester about 4'-0" diameter. Main ducts in the Acid Plant area are of steel about 4'-6" diameter. All weak acid piping is of fiberglass reinforced polyester (FRP), PVC or CPVC. Valves are of Alloy 20 construction. Substantially all of the 93% and 98% acid piping is centrifugal cast iron. Valves are Alloy 20 with teflon packing. Product acid piping is black iron.

SULFURIC ACID PLANT

The cleaned process gas enters the 600 ton per day, metallurgical type contact sulfuric acid plant; it first passes through the packed drying tower countercurrent to a flow of 93% H_2SO_4 to remove the water vapor contained in the gas. The drying tower is a vertical acid brick lined steel tank 14'-7" I.D. brick by 41'-0" high. The lower section is packed with one layer of 6" ceramic cross partition rings and 12 feet of dumped 3" ceramic Intalox saddles. Acid distribution across the tower diameter is by a cast iron weir trough which is above the packing and has submerged discharge through closed downspouts. The reduced top section of the tower, approximately 9'-0" I.D., contains a teflon pad mist eliminator. Sufficient acid is circulated over the tower so that the water vapor removed does not significantly reduce the strength of the acid in

a single pass over the tower. Entrained acid in the gas is removed by the mist eliminator pad.

The clean dry gas and the dilution air (allowed to enter the stream of gas from the mist precipitator) are now ready to pass through the remainder of the plant.

From the converter mouths to this point the gases are under suction developed by two parallel operated single stage centrifugal air blowers. Each unit is designed to handle 21,250 SCFM (32°F and 29.92" Hg) of dry process gas with inlet conditions of 130°F and 12.7 psig. Discharge pressure is designed at 147" W.C. Each drive motor is rated at 1,000 H.P.

Gases from these blowers flow through the shell sides of three gas heat exchangers (arranged in series) to be heated. The cold heat exchanger is a vertical, tubular heat exchanger with steel shell and steel tubes. There are 1,750 tubes that are 1 3/4" O.D. by 24'-0" long; the shell is about 11'-9" I.D. The tube side cools the gas leaving the fourth catalyst chamber pass; the shell side partially heats the SO_2 gas before it enters the intermediate heat exchanger. This unit has 500 tubes that are 3" O.D. by 14'-0" long; the shell is about 8'-6" I.D. The tube side cools the gas leaving the second catalyst chamber pass; the shell side partially heats the SO_2 gas before it enters the hot heat exchanger. This unit has 1,290 tubes (alonized both sides) that are 2" O.D. by 20'-0" long; the shell is about 11'-3" I.D. The tube side cools the gas leaving the first catalyst chamber pass; the shell side heats the SO_2 gas which is to enter the first catalyst chamber pass.

The catalyst chamber (converter) is a vertical cylindrical steel tank which is 27'-6" I.D. by about 41'-6" high. There are four passes or catalyst beds. The first pass catalyst is supported on Meehanite grids; all other layers of catalyst are supported on heat resistant C.I. grids. The first pass

has a lining of high temperature insulating fire brick and is metallized down to the division plate. 122,000 liters of Type 210 Monsanto Enviro-Chem vanadium pentoxide catalyst is used; all catalyst beds have 2" layers of quartz pebbles top and bottom.

Sulfur dioxide is partially converted (minimum conversion rate overall is 96% of SO_2 to SO_3) to sulfur trioxide as the gas passes through the first catalyst mass. This conversion uses oxygen and produces heat. The gas is cooled in the hot heat exchanger before it enters the second catalyst mass. More conversion and generation of heat takes place. The gas is cooled in the intermediate heat exchanger before it enters the third catalyst mass. More conversion of SO_2 to SO_3 takes place and generates heat. These hot gases flow through an exterior cooling loop before entering the fourth catalyst mass for final conversion of SO_2 to SO_3. The gases are cooled in the cold heat exchanger before they go to the absorbing tower.

A natural gas or diesel oil fired preheater furnace supplies hot gas to a shell and tube heat exchanger. This system is designed to heat 15,000 SCFM of process gas to the desired catalyst chamber inlet temperature. It is utilized to bring the catalyst in the catalyst chamber up to the temperature level required for the catalytic conversion of SO_2 to SO_3, whenever catalyst temperatures have decreased due to a prolonged shutdown. The preheater system may also be used to supplement the heat requirements of the catalyst system, if an operating upset or low SO_2 gas strength reduces the heat available for the conversion reaction.

The absorbing tower is a vertical, acid brick lined, steel tank which is 14'-7" I.D. the brick by approximately 42'-9" high. The tower is packed in the lower section with one layer of 6" ceramic cross partition rings and 14 feet of dumped 3" ceramic Intalox saddles. There is a cast iron weir acid

distributor above the packing; this weir has submerged discharge through closed downspouts. The reduced top section of the absorbing tower is about 8'-9" I.D.; it contains an Alloy 20 pad mist eliminator.

The SO_3 laden gases pass upward through the absorbing tower countercurrent to a flow of 98% H_2SO_4 which absorbs the SO_3 contained in the process gas. Enough acid is circulated over the tower so that the SO_3 absorbed does not significantly increase the strength of the acid in a single pass over the tower. The process gas then contains nitrogen, trace amounts of unabsorbed SO_3, unconverted SO_2, and acid mist. As the gas passes through the mist eliminator, the acid mist particles are almost completely removed. This gas should not exceed 2,500 ppm by volume of SO_2. The gas passes through a long mild steel duct to the base of the 360 foot concrete stack for dispersion to the atmosphere.

The strong acid circulating systems utilized to dry the SO_2 gas from the purification system (humidifying tower, gas cooling tower, and mist precipitator) and to absorb the SO_3 gas from the catalyst chamber are separate systems. Each system has a pump tank (18'-0" I.D. by 7'-0" high; vertical, acid-brick lined, steel closed tank), a circulating pump (vertical, centrifugal, corrosion resistant pump; 2,200 gpm for drying; 2,300 gpm for absorbing), acid coolers and a piping system. The systems are interconnected to permit control because the strength and the temperature of the drying acid must be maintained within certain limits to obtain the most efficient drying of the process gas which passes through the drying tower. To obtain the most efficient absorption of SO_3 from the process gas passing through the absorbing tower the strength and temperature of the absorbing acid must be maintained within certain limits.

Acid circulated over the drying tower is weakened by the water vapor removed from the SO_2 gas; acid circulated over the absorbing tower is strengthened by the absorption of the SO_3. Approximately 35 gpm of 98.0% acid is diverted to

the SO_2 Absorption Plant. To counteract these strength changes, the absorbing tower acid is pumped to the drying tower pump tank. If the 98% H_2SO_4 transferred to the 93% pump tank keeps the 93% tank acid above the range of 93.19 to 93.90% H_2SO_4, water is added to dilute the acid.

The dilution of the drying acid by the water vapor from the process gas and the addition of about 35.5 gpm of 96.5% acid from the SO_2 drying tower at the SO_2 Absorption Plant to the 93% pump tank raises the temperature of the acid. To reduce the temperature the 93% acid is passed through twelve teflon tank type coolers (located in the 93% pump tank) which can cool 1,700 gpm of acid to 130°F with the cooling water at 81°F. The acid is then returned to the drying tower.

The absorption of the SO_2 and any addition of water to the 98% pump tank raises the temperature of the absorbing acid. To reduce the temperature the absorbing acid is passed through twelve teflon tank type coolers (located in the 98% pump tank) which can cool 2,200 gpm of acid to 175°F with the cooling water at 81°F. This acid is recirculated to the absorbing tower.

Water for these teflon heat exchangers is filtered by eight filter units each of which is 36" diameter and contains 44¼" of filter material: 14 cu. ft. of 5/8" x 1" filter gravel at the bottom, 3½ cu. ft. of 3/16" x 3/8" filter gravel in the middle, and 7 cu. ft. of 0.81 mm x 1.5 mm torpedo sand on top. These units are periodically back flushed.

As the acid from the 93% pump tank is recirculated to the drying tower, part of the flow is diverted to the crossflow stripping tower. This tower is a vertical acid brick lined, steel tank which is 4'9'" I.D. the brick by 29'-3" high. The lower section is packed with one layer of 6" ceramic cross partition rings and twelve feet of 3" C.P. rings. The top section of the tower contains a teflon pad mist eliminator. Air is used to strip out dissolved SO_2 from the acid. SO_2 should be 60 ppm maximum. Part of this acid returns to the 93% pump

tank; part of it is cooled in teflon coolers before going to storage tanks as product acid in the 93.19% to 93.90% H_2SO_4 range. These teflon coolers are of the shell and tube type capable of cooling 75 gpm of acid to 110°F. The product acid pump is an inline, horizontal, centrifugal pump constructed of Alloy 20. The two product acid storage tanks are each 50'-0" in diameter by 23'-9" high. Storage can be 327,000 gallons in each. Product acid is loaded into tank trucks or railroad tank cars for transportation to market.

WATER COOLING TOWER

The cooling water system has been designed to supply a continuous flow of cooled water to various equipment cooling jackets, sample coolers, and heat exchangers throughout the Converter Gas Cooler and auxiliary systems and throughout the Acid Plant and SO_2 Absorption Plant.

The cooling tower is 79 feet long, 73 feet wide and 47 feet high; it is divided into two cells. Structural members and decking are of redwood construction; the basin is concrete; the remainder is of plastic or resin construction. This tower is designed for double cross flow.

Hot water from the process equipment returns to a distribution deck at the top of the tower, flows downward through the tower fill, and is pumped back to the process equipment. Nominally 25,000 gpm can be cooled from 101°F to 81°F with an ambient wet bulb temperature of 75°F (maximum).

Mechanical equipment at the tower consists of two fans and four water circulating pumps (each at 7500 gpm).

Three chemicals are added to the cooling tower water. One is an alkaline solution of sodium chromate and sodium phosphonate for corrosion inhibition. The second is an alkaline solution which keeps any solids in the water suspended so fewer deposits will occur. The third is an amine type chemical to control bacteria and slime. Both the pH and conductivity are monitored. As the

conductivity increases, the cooling water purge valve will open and the feed rate of the corrosion inhibitor will increase. Water is purged to the concentrator tailing launder.

Specific items served in the gas cooler area are as follows: steam condenser; steam jet air ejector intercondenser and aftercondenser; gas cooler feed pumps (pump oil coolers and seal coolers); boiler feed pump oil coolers, seal coolers and bearing coolers; sample coolers; and soot blower air compressor high and low pressure cylinder jackets, first and second stage intercoolers and aftercooler.

Other cooling water users are the seven SO_2 absorption tower tray coolers, the DEA cooler, the stripping tower rectifier cooler, the SO_2 Absorption Plant drying acid coolers, the SO_2 condenser, the coolers for the gas cooling towers at the Acid Plant and SO_2 Absorption Plant, the 93% and 98% acid coolers in the pump tanks, the product acid coolers, SO_2 Absorption Plant sample coolers, the SO_2 fan lube oil cooler, the SO_2 compressor, the Acid Plant fan, lube oil coolers and the instrument air compressor.

SOOTBLOWER AND INSTRUMENT AIR COMPRESSORS

Sootblower air is supplied by the sootblower air compressor which is located in a separate air compressor building. This is a three stage, two cylinder piston type, oil lubricated, air compressor designed to deliver 853 cubic feet of air per minute at a discharge pressure of 500 psig. The compressor is designed to run continuously with the air flow being controlled by cylinder unloaders and clearance pocket valves. The first stage discharges at 42 psig, the second stage at 161 psig, and the third stage at 500 psig. This air is discharged into an air receiver which acts as a surge chamber for the sootblower system. Sootblower air flows from the receiver through a pressure control valve which reduces the pressure to 210 psig for use by the sootblowers.

The instrument air compressor is of the oil-free, non-lubricated type. It is a Y-type, 2 stage unit with a capacity of 600 CFM at 13.80 psia and 110°F at intake and a discharge pressure of 100 psig. Air is dried in a desiccant type air dryer before being distributed throughout the Gas Treatment facilities for air controlled instrumentation and for operation of air operated valves.

CONTROL ROOMS

Four control rooms were provided:

1. Reverberatory electrostatic precipitator: Power and controls for precipitator; power distribution for some smelter auxiliaries; instrumentation for stack monitoring.
2. Converter electrostatic precipitator: Power and controls for precipitator.
3. Converter waste heat boilers (gas coolers): Controls and instrumentation for these facilities; controls for balloon flue drag chains; controls for dampers related to balloon flue.
4. Acid Plant and SO_2 Absorption Plant: This building is 40'-0" wide by 58'-0" long overall. Of the length about 21 feet is for a control room; 9 feet is for toilets and mechanical facilities; and 28 feet is for electrical power distribution equipment. The control room has panels on which information is indicated and/or recorded, on which are located controls for various units, and on which alarms warn of significant changes in process conditions.

INSTRUMENT REPAIRS

Added onto the Acid Plant and SO_2 Absorption Plant Control Room building is an instrumentation service shop. This shop is 16'-8" by 40'-0". It has facilities for instrument maintenance and spare parts storage.

COMMUNICATIONS

Communications consist of (1) the public telephone system with telephones located in the Converter Waste Heat Boiler (Gas Cooler) Control Room and in the Acid Plant and SO_2 Absorption Plant Control Room; of (2) nine portable radio sets which are in use as follows: 2 for the Gas Coolers, 2 for the Instrument Sub-Foremen, and one each for the Acid Plant Operator, the SO_2 Absorption Plant Operator, the Repairman, the Gas Treatment Plant Foreman, and the Gas Treatment Plant Repair Foreman; and of (3) a Gai-Tronics Industrial Communications System which has stations at the following locations: Reverberatory electrostatic precipitator control room, operator's station for No. 1 and No. 2 Converters, operator's station for No. 3 Converter, Converter Waste Heat Boiler Control Room, Powerhouse, Converter electrostatic precipitator Control Room, air compressor building, Acid Plant and SO_2 Absorption Plant Control Room, at the Acid Plant acid loading station, and on the ground floor level of the SO_2 Absorption Plant.

PERSONNEL

Manpower requirements are as follows:

1. Converter Waste Heat Boilers (Gas Coolers): four Waste Heat Boiler Firemen (one each shift plus one swingman); one Boiler Repairman; one Boiler Repairman Helper; one sub-foreman. All of these are supervised by the Power Plant Foreman.
2. Remainder of Gas Treatment Facilities: three Acid Plant Operators; three SO_2 Absorption Plant Operators; one Acid Plant Helper; one Trainee; one Repariman; one Repairman Helper; two Instrument Electrician Sub-Foremen (also work in Gas Cooler area); one Cottrell Lead Operator. These men are supervised by one Gas Treatment Plant Foreman and one Gas Treatment Plant Repair Foreman.

PROBLEM SUBMATION

Primary problems have been (1) deterioration of dome of the humidifying tower due to wrong material selection; (2) inadequate mist precipitator capacity; (3) deterioration of tubes in cold heat exchanger because of (2); and (4) piston and valve problems for sootblower air compressor. Corrections for these are underway. Compliance goal is to be reached by December 31, 1974.

For presentation at Smelter Division, Arizona Section, AIME meeting at Ajo, Arizona, on April 26, 1974.

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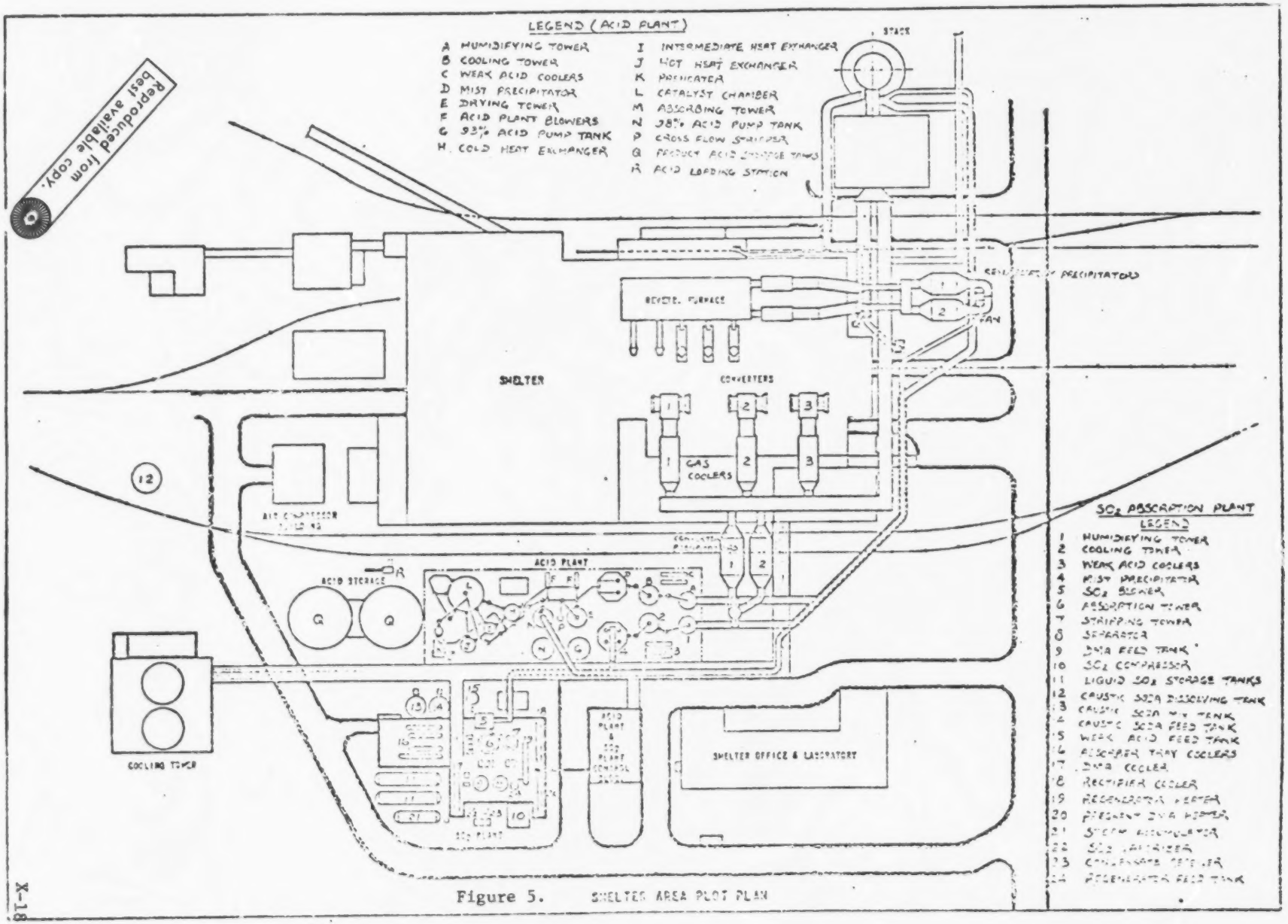

Figure 5. SHELTER AREA PLOT PLAN

SO_2 ABSORPTION PLANT AT THE NEW CORNELIA BRANCH OF PHELPS DODGE CORPORATION, AJO, ARIZONA

W. J. CHEN
Gas Treatment Plant Foreman

Introduction

The SO_2 Absorption Plant at Ajo is designed to treat the Reverberatory furnace gases, or the converter gases, or a combination of both. Sulfur dioxide gas from these gases is absorbed by an organic solvent known as dimethylaniline (DMA) in an absorption tower. Subsequent recovery of SO_2 gas is achieved by thermal stripping in a stripping tower. The gaseous SO_2 is then dried, compressed, and condensed to a liquid form. Liquid SO_2 is stored under pressure. As the Acid Plant operations dictate, liquid SO_2 is vaporized to supplement the supply of gaseous SO_2 to the Acid Plant.

Process Description

Reverberatory gases from the reverberatory electrostatic precipitator are discharged by an induced draft fan through a long 6-foot I.D. insulated duct to the SO_2 Absorption Plant. Since the SO_2 Absorption Plant is not designed to treat all of the gases from the reverberatory furnace, part are discharged to the 360-foot stack. This gas distribution is made by a butterfly damper between the fan and the stack. A butterfly damper is installed between the reverberatory precipitator fan and the inlet to the SO_2 Absorption Plant gas cleaning facilities. Another similar damper is installed between the converter electrostatic precipitator outlet and the inlet to the SO_2 Absorption Plant gas cleaning facilities. These two dampers allow the SO_2 Absorption Plant to operate with straight reverberatory gases or the combustion of both gases.

Prior to entering the SO_2 Absorption Plant, the gases are cleaned by a series of gas cleaning equipment. The gas cleaning section consists of a humidifying tower into which the gases enter at 400°- 500°F, a packed cooling

tower, and a mist precipitator. At the humidifying tower, the gases are evaporatively cooled, and some of the remaining particulate matter is removed. The humidifying tower, comprised of two sections, is 15 feet 7 inches in diameter. The lower section is constructed of steel which is lined with lead and with acid-proof brick. The upper dome is constructed entirely of 316L stainless steel with no interior lining. Solution is pumped to the upper dome and distributed over the tower diameter by spray nozzles made of Carpenter 20 material. The weak acid solution is circulated through the tower without cooling. The circulating pump for the humidifying tower is a centrifugal pump. Its impeller and casing are made of Carpenter 20 material. The related piping material is fiberglass reinforced plastic. An automatic level control allows any solution level build-up due to drain back from the cooling tower and mist precipitator to be purged to the concentrator tailing launder. The gases from the top of the humidifying tower enter the side of the cooling tower which is constructed of steel, lined with lead and with acid-proof brick and packed with polypropylene Intalox saddles. The dish shaped roof is made of fiberglass reinforced plastic. The weak acid solution is pumped through a series of six shell and tube heat exchangers before going to the upper section of the tower. The circulating pump for the cooling tower is identical to that of the humidifying tower. The shell and tube exchangers are designed to operate at 75 psia on the tube side and 50 psia on the shell side. The tubes are made of impervious graphite material whereas the shell is made of steel. The weak acid solution is distributed evenly over the tower diameter by distribution troughs and as it runs down through the packing, it cools the ascending gases to 90° F. and removes more of the particulate matter. Make-up water is added to this tower. Excess water is drained to the humidifying tower for disposal. The gases from the cooling tower enter the bottom chamber of the mist precipitator which is designed to remove sulfuric acid

mist from the gas stream to avoid corrosion of ensuing equipment downstream. As the gases pass through the lead tubes, any acid mist or remaining dust particles are positively charged and attracted to the inside wall of the grounded tubes. Droplets of acid run down the tubes and carry particulate matter with them to the bottom chamber where they are drained by gravity to the humidifying tower for disposal.

The gases are drawn through the gas cleaning section by a 1000 HP blower, whose impeller is 316L stainless steel, and discharged into the absorption tower. The capacity of the blower is 49,910 ACFM. Its speed is 3500 rpm. The designed inlet pressure is minus 28 inches of water whereas the discharge pressure is 82 inches of water. A chain operated valve ahead of the blower controls the volume of gases into the SO_2 Absorption Plant. The absorption tower is 13 feet in diameter by 66 feet high and consists of the absorbing section, soda scrubbing section, and acid scrubbing section. The absorbing section at the bottom consists of 8 valve trays, three feet apart, and a mist eliminator. The entire section is constructed of 316L stainless steel. Dimethylaniline from a stainless steel DMA feed tank (which is 12 feet in diameter by 16 feet high) is cooled by a heat exchanger and fed into tray 8. DMA flows from one side of a tray to the other side and then down into the next lower tray. As the gases flow upward, SO_2 is absorbed by the DMA. Most of the absorption is accomplished in the lower trays resulting in a decreasing amount of SO_2 available for absorption in the higher trays. Tremendous amounts of heat are released during absorption, thus the DMA and SO_2 absorbed are removed from a higher tray, pumped through a shell and tube heat exchanger for cooling, and returned to the next lower tray. The tubes through which the DMA-SO_2 stream pass are made of 316L stainless steel, whereas the shell is constructed of mild steel. Seven heat exchangers and seven tray cooler pumps are required in this section. Both the impellers and the casings of these pumps are made of 316L stainless steel as is all the related piping.

The soda scrubbing section of 316L stainless steel at the middle of the absorption tower consists of two bubble cap trays, two feet apart, and a mist eliminator. The main function of this section is to remove the remaining SO_2 from the gas stream and to provide a solution to neutralize the acid from the acid scrubbing section. A 6% soda ash solution (or caustic soda solution) is prepared in a 15' x 12' mix tank and transferred to a feed tank of similar size. Both tanks are made of mild steel. The soda ash solution is fed into the upper tray of the section and flows by gravity into the lower tray and then into a stainless steel collection tank which is 4 feet in diameter by 5½ feet high.

The acid scrubbing section at the top of the absorption tower consists of nine bubble cap trays and a mist eliminator. This entire section and internals are constructed of Carpenter 20 material except the mist eliminator which is made of polypropylene. The section is designed to remove any DMA vapor before the gas stream is discharged to the atmosphere through the 50-foot fiberglass stack. The gases from the stack contain 15 ppm DMA and about 500 ppm SO_2. 5% sulfuric acid is prepared in a 316L stainless steel feed tank which is 10 feet in diameter by 10½ feet high. This weak acid feed tank is lined with 1/4" of chlorobutyl rubber to eliminate corrosion problems which have been experienced since the start-up of the SO_2 Absorption Plant. The weak acid is pumped to the top tray and overflows to the next lower tray. The impeller and casing of the centrifugal weak acid feed pump are made of Carpenter 20 material. The piping material from the pump to the weak acid scrubbing section is made of either Carpenter 20 or chlorinated polyvinyl chloride material. DMA vapor in the exhaust gases is removed by the weak acid solution which flows by gravity from the bottom tray to the stainless steel collection tank where neutralization takes place. The pH of the solution is monitored in order to adjust the soda ash solution feed rate to the absorption tower and is maintained between 7.0 and 7.5. The solution from the collection tank flows by gravity to a separator tank.

The pregnant DMA (DMA loaded with SO_2) from the absorbing section of the absorption tower is heated in the tube side of the pregnant DMA heat exchanger, made of 316L stainless steel, before entering the stripping tower.

The stripping tower, which is 7½ feet in diameter by 72½ feet tall, is entirely constructed of 316L stainless steel. This tower also consists of 3 sections: regenerating, stripping, and rectifying. The regenerating section, which generates steam for stripping purposes, consists of 7 bubble cap trays and a mist eliminator. Water and impurities from the stainless steel regenerator feed tank, which is 6 feet in diameter by 6 feet high, enters the top tray of the section. Water flows from one side of the tray to the other side of the tray and overflows to the next lower tray. Water from the bottom of the regenerating section is pumped through a regenerator heater where steam is generated and is fed back to the regenerating section. Excess water from the system is dumped to the concentrator tailing launder. The pH of the purge water is also monitored for controlling the feed rate of soda ash solution to the absorption tower.

The stripping section consists of 14 valve cap trays and a collection tray. Pregnant DMA, after taking up heat from the stripped DMA in the pregnant DMA heater, enters the top tray of the section. As the DMA flows down through the stripping section in a split flow manner, SO_2 is stripped out of the DMA by the steam from the regenerating section. In order to attain an efficient stripping of SO2 gas from the DMA, a sufficiently high temperature of about 176°F must be maintained at the top tray of the stripping section. The stripped DMA from the bottom of the stripping section is pumped through the shell side of the pregnant DMA heat exchanger. This DMA loses its heat before entering the separator tank which is 10 3/4 feet in diameter by 18½ feet high and constructed entirely of stainless steel. The separator tank allows the separation of DMA - water mixtures into a DMA phase and a water phase. DMA, being lighter, overflows from

the top of the separator tank into the DMA feed tank for reuse. The water phase underflows from the separator tank through a dip pipe into the regenerator feed tank for steam generation and disposal.

The rectifying section of the stripping tower consists of five bubble cap trays, a collection tray, and a mist eliminator. This section is designed to condense both DMA vapor and steam. Make-up water is fed into the top tray and flows downwards. The hot gas consisting of SO_2, steam, and some DMA vapor enters the rectifying section through the two chimneys in the collection tray from which it is pumped through a rectifier cooler and circulated back to the top tray. As the cold solution flows downward, both steam and DMA vapor are condensed and flow through a downcomer into the stripping section. This stream of condensed steam and DMA mixes with the stripped DMA in the stripping section and flows into the separator tank for DMA and water separation.

The SO_2 gas which is saturated with water vapor is then drawn by the SO_2 compressor through a fiberglass duct into the bottom of a packed drying tower which is 4½ feet in diameter by 21½ feet high and is constructed of Carpenter 20 material. The drying tower is packed with ceramic material. 98% sulfuric acid from the Acid Plant is cooled by a series of four shell and tube teflon heat exchangers and flows into a distribution trough in the drying tower. Moisture in the SO_2 gas stream is removed. The diluted sulfuric acid returns to the 93% pump tank in the Acid Plant. The dried SO_2 gas then enters the SO_2 compressor which is a two stage, reciprocating compressor with automatic volume controls. When SO_2 availability decreases, the compressor unloads into the inlet bottle rather than the product line. The SO_2 is compressed to 120 psig and is passed through the tube side of a condenser where cooling water on the shell side condenses the hot, gaseous SO_2 into liquid SO_2. The product liquid SO_2 then flows to the two steel horizontal storage tanks which are 10 feet in diameter by 50

feet long. When SO_2 gas from the Smelter is unavailable or is low in strength, liquid SO_2 is vaporized in a vaporizer with steam to supplement the Acid Plant operation.

Steam from the converter gas coolers is stored in a steam accumulator in the SO_2 Absorption Plant for use in the regenerator heater for the stripping tower and in the SO_2 vaporizer. Condensate from the steam system is returned to the converter gas cooler area or to the Power House for reuse.

The SO_2 Absorption Plant is equipped with extensive instrumentation to monitor its operation. Both electronic and pneumatic instruments are used to control the level of various feed tanks, and various trays in the absorption tower and stripping tower. Differential pressure transmitters in the field transmit process variable signals to the indicator-controllers in the control room. These enable the operators to correct any deviation from a normal set point remotely and with minimum time delay. Audible (HIGH and LOW) alarms are installed to aid the operators in regulating the process variables. Audible alarms are also installed on every critical piece of equipment to indicate malfunction of the equipment so that the operators can react accordingly.

Temperature, pressure, conductivity and pH instruments are installed at strategic positions. The outlet gas temperature from the humidifying tower is interlocked with the SO_2 blower operation. A high temperature at the humidifying tower outlet will automatically shut off the SO_2 blower. This will stop the gas flow from the reverberatory furnace to the SO_2 Absorption Plant in order to protect the low heat resistant fiber glass reinforced plastic duct.

SO_2 analyzers are installed to monitor the SO_2 concentration of the entrance and exit gases of the Plant. The SO_2 totalizers which are installed recently reveal that the inlet gases average about 1.5% SO_2 whereas the exit gases average about 400 ppm SO_2.

General Discussion

The SO_2 Absorption Plant is capable of absorbing SO_2 from smelter gases ranging from 1.5% to 9.0% of sulfur dioxide. The governing factor depends on the volume of 100% SO_2 gas that the SO_2 compressor is capable of handling. The Plant has not been able to operate for an extended period of time, mainly due to mechanical failures in various pieces of equipment. The first problem of this nature was the bearing failure on the motor of the SO_2 blower. This has been corrected. Another major problem is attributed to frequent overhaul of the SO_2 compressor. Corrective measures to alleviate this problem consist of the installation of a spare compressor; installation of a weak acid scrubbing tower between the stripping tower and the drying tower to eliminate any DMA vapor carryover; installation of a booster pump for additional drying acid to assure complete removal of moisture from the SO_2 gas; and additional cooling capacity for the drying acid to lower the inlet temperature of the SO_2 gas to the compressor.

Operation at the designed rate in the SO_2 Absorption Plant has not been attained so far, mainly due to the inadequacy of the mist precipitator. Additional mist precipitators will be installed. Other problems in the SO_2 Absorption Plant are: 1. Excessive corrosion noted on the weak acid feed tank and associated pipings; 2. Rapid deterioration of the upper 316L stainless steel dome for the humidifying tower; 3. Extensive leakage on the partition trays in the absorption tower causing undesirable conditions. Corrective measures for these problems are under way. In addition, difficulty has been experienced in obtaining supplies of DMA.

For presentation at Smelter Division,
Arizona Section, AIME meeting at
Ajo, Arizona, on April 26, 1974.

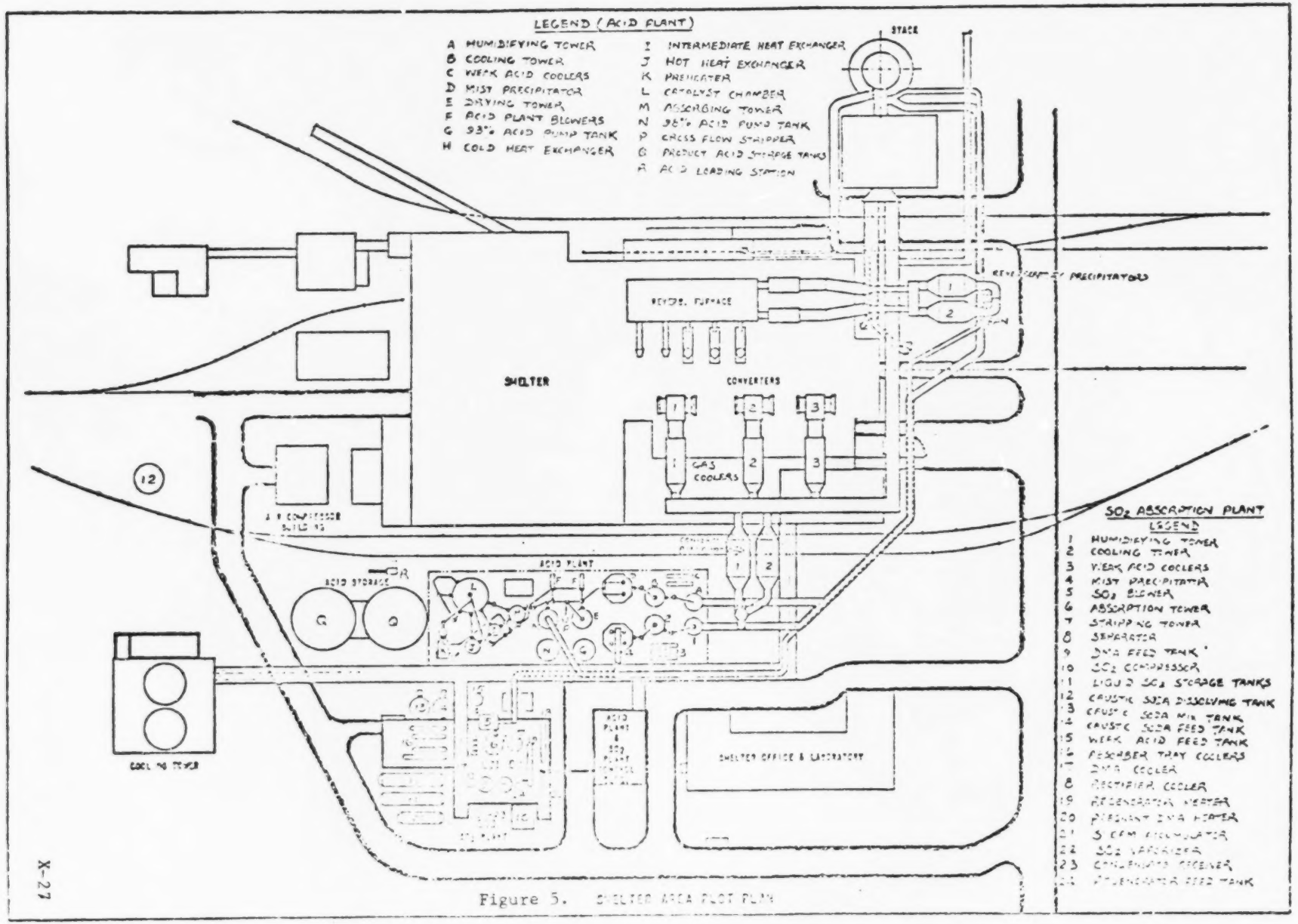

Figure 5. SHELTER AREA PLOT PLAN

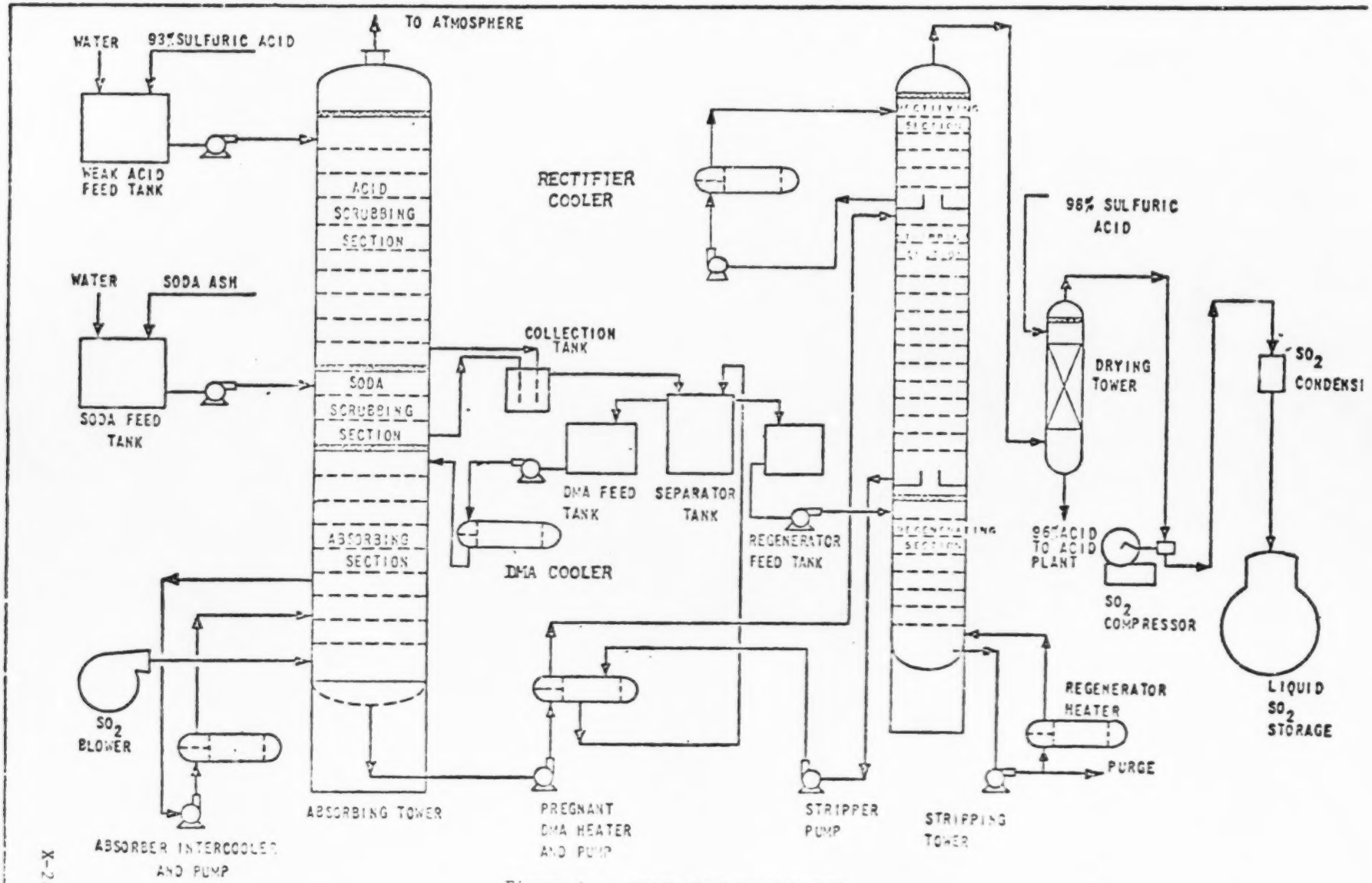

Figure 6. SCHEMATIC FLOW SHEET SO_2 ABSORPTION PLANT

USE OF THE GAS COOLERS (WASTE HEAT BOILERS) IN THE CONVERTER DEPARTMENT AT THE NEW CORNELIA BRANCH OF THE PHELPS DODGE CORPORATION, AJO, ARIZONA

By James B. McBiles
Power Plant Foreman

Introduction:

On December 21, 1970, construction was started on a Smelter Gas System Modification at the New Cornelia Branch, Phelps Dodge Corporation, Ajo, Arizona. On November 20, 1973, modifications were essentially completed. In these new gas treating facilities, cooling of the copper exhaust gases is necessary for proper operation. The first gas cooler was placed in operation on November 17, 1972.

Process Description:

This cooling process was accomplished by installing three identical converter gas coolers (waste heat boilers) each serving a separate Peirce-Smith copper converter. The main function of these converter gas coolers are two-fold. First, and primarily, they are to cool the converter exhaust gases; and secondly, to produce a steam supply to be used downstream in the SO_2 Absorption Plant. The gas cooling operation can be broken down into four (4) systems:

A. Steam and Gas Cooling Systems.

B. Condensate System.

C. Feedwater System.

D. Miscellaneous Mechanical Systems.

Steam and Gas Cooling Systems: The converter exhaust gases which are introduced into the gas cooler cause sudden and extreme load changes. Gases going in cause a load increase; stoppage of gas flow causes a load decrease. In order to fully obtain stabilized circulation of boiler water under these extreme load changes, a forced circulation type of boiler has been adapted for this application. The forced circulation type boiler differs in the following respects from the conventional natural circulation boiler. All the water circulation necessary for the boiler is done by the boiler water circulation pump. An orifice is provided at the inlet of each boiler tube so that boiler water is circulated according to the thermal load of each circulating circuit. Boiler water is fed to the circulation pump from the drum through a downcomer. From the pump it enters the boiler inlet header through the supply pipe. Here in the inlet header the boiler water is distributed through the orifices to give the boiler tubes their necessary water supply. While the water is being circulated, heat is absorbed and causes a mixture of steam and water. This mixture is collected in the boiler outlet header and enters the steam drum.

The separation of steam from the steam-water mixture is carried out by the turbo-separator and dry screen which are installed in the steam drum. The boiler water which is separated from the steam is then mixed with the boiler feedwater that is entering the drum. The mixed boiler water then flows from the drum through the downcomer and back in to the circulating pump.

Each gas cooler has two 1,350 gallon-per-minute forced circulating pumps. One of these pumps is continously running; the other is on

standby service, set to start immediately if the operating pump fails to provide sufficient cooler water circulation flow.

The operation of a copper converter produces sudden surges of hot exhaust gases when the converter rolls into operating position; this gas flow is suddenly stopped when the converter rolls out of operating position.

In order to prevent thermal shock to the boiler during these rapid load changes, and to prevent the tube-wall temperature from dropping to near the acid "dew point" (about 400° F), the temperature and pressure of the steam drum is maintained near the operating condition even when the converter is idle. Auxiliary steam is fed automatically to the steam drum through a sparge line, while the gas cooler is idle. The forced circulating pumps run continually, even during idle periods.

During the operation of the converter gas coolers, the steam produced in the gas coolers flows in to the main steam header which is equipped with a back-pressure regulating control valve set to keep the steam drum pressure at operating conditions (540 psig). From the main header the steam flows to the deaerator to maintain a constant deaerator pressure and to supply steam to the steam accumulator at the SO_2 Absorption Plant. When an excess of steam is produced, the main header pressure will start rising until it reaches approximately 545 psig. At this poin another pressure control valve will open and let the excess steam into the steam condenser. During periods when no steam is being produced in the Converter Gas Coolers, pressure is maintained in the main steam header by the 800 psig plant steam system (from the reverb waste heat boilers) through a pressure control valve which is set at 535 psig. This 800 psig plant steam system also supplies steam for the sparging steam in the three

gas cooler drums to maintain near operating pressure and temperature, steam for the three turbines that drive the circulating pump for each gas cooler and steam for the jet air ejectors at the steam condenser.

When the gas cooler is in operation (converter rolled in), gases as hot as 2500° F are produced and forced into the converter exhaust hood. Ambient infiltration air is drawn past the hood seals into the gas stream lowering the mixed gas temperature to approximately 1200° F.

The gas then enters the converter gas cooler where heat is given up to water circulating through the gas cooler tubes, lowering the gas temperature to 550° F.

When the copper converter "rolls in", a sudden volume increase, or swell, occurs when steam bubbles are formed in the gas cooler tubes and cause an abrupt rise in the steam drum level. Similarly, when the converter "rolls out", steam bubbles quickly collapse, or shrink, causing an abrupt drop in the drum level. The magnitude of this swell and shrink has been taken into consideration in the design of these boilers.

Design pressure for these boilers are 600 psig, operating at 540 psig. Outlet steam temperature is 478° F and feedwater temperature is 248° F. Inlet gas temperature is 1200° F, and outlet gas temperature is 650° F, plus or minus 54° F. Boiler tube heating surface is 14,565 sq. ft., and water wall heating surface is 1,960 sq. ft. Steam drum internal diameter is 72.44 inches, and the internal length is 18' 8.2". The total boiler water capacity is 6,470 gallons. These boilers are

designed to handle 47,000 pounds-per-hour evaporation safely.

Condensate System: The primary purpose of the condensate system is to condense the steam that is produced by the gas coolers, but is not needed, and to start the resulting condensate back to the gas cooler feedwater system. The condensate system consists of a condenser, hotwell and condensate return pump.

The condenser is a tube and shell type of heat exchanger. Steam is condensed on the outside of the tubes in the condenser shell and collects in the hotwell. The hotwell is a storage tank located on the bottom of the steam condenser shell to provide surge capacity for the condensate system and to provide the condensate pumps with proper suction pressure. The steam is condensed in the shell of the condenser by transferring its heat into the cooling water flowing through the condenser tubes. The heat energy that was initially removed from the converter exhaust gases by the gas coolers is transferred to the cooling water system and released to the atmosphere by the cooling tower. The condenser shell operates under vacuum conditions. A steam jet air ejector is used to evacuate all of the air and non-condensable gases from the steam side of the condenser. The flow of condensate from the hotwell is through the condensate return pumps and into the deaerator.

The condensate level is maintained in the hotwell by steam being condensed in the steam condenser or by the condensate being returned from the condensed steam at the SO_2 Absorption Plant. If this does not maintain the hotwell level, condensate from the Power Plant will

automatically feed under low level conditions. There are two condensate return pumps, one having enough condensate capacity for the operation of two gas coolers.

Condensate enters the deaerator from the condensate return pumps at a temperature ranging from 80° F to 120° F, depending on the condenser vacuum.

This deaerator is a two-stage spray tray type combination feedwater heater and counterflow gas/liquid scrubber. The deaerator pressure is controlled at 15 psig. Since the deaerator contains both steam and water in equilibrium, the vessel will operate at saturation temperature of 248° F. This will increase the condensate temperature as it sprays into the deaerator and will remove most of the dissolved gases.

Feedwater System: The gas cooler feedwater system consists of two boiler feed pumps and a drum level control system. These feed pumps are eight-stage centrifugal pumps, designed to supply enough feedwater for two gas cooler operation. Feedwater enters the feed pump from the deaerator storage tanks. This makes it very important to maintain proper deaerator water level to provide the pump with adequate suction pressure. The boiler feedwater pumps discharge into a common gas cooler feedwater header at about 650 psi. With one pump running and the other pump on standby service, the standby pump will start automatically if the header pressure drops too low.

Each gas cooler has identical feedwater control systems, separate from each other, but all connected to the common feedwater header. The feedwater is fed to the drum through a regulating valve that is controlled by a three-element control system. This three-element control system receives inputs from steam flow, drum level and feedwater

flow. Each drum level control system operates primarily to balance feedwater flow with steam flow by modulating the feedwater control valve. However, the steam flow signal is adjusted by a drum level correction. This correction is developed by comparing the actual drum level with the drum level set-point. The drum level set-point is developed as a function of steam flow. At zero steam flow the drum level set-point will be at the lower end of its range (-8"). Under full steaming conditions the drum level set-point will be at or near the top of its range (+8"). Normal drum level will be any level in this range. To prevent any high level condition a high level dump valve is provided, which will automatically dump water from the steam drum into the blowdown system. This valve is operated from a level signal that is independent of the three-element control system. This valve will automatically close just before the normal drum level set-point is reached.

When the gas coolers are in an idle condition, the pressure and temperature is maintained by the sparge steam system. This sparge steam condenses, thereby raising the water level in the drum. A separate drum level control loop is provided to prevent this undesirable accumulation of boiler water. This control loop consists of a controller and a control valve. This controller attempts to maintain the minimum drum level set-point in a low-low, or no steaming condition. As the steam flow begins to rise, this valve will automatically close. This blowdown water is also dumped into the blowdown system.

Miscellaneous Mechanical Systems: All blowdown condensate from steam traps, and other waste condensate flows to a blowdown header. This header is connected to a blowdown tank designed to accept hot flashing water. The water is collected in the blowdown tank and flows by gravity to

the sewer, or to the condensate receiver in the SO_2 Absorption Plant. This condensate is automatically pumped to the steam condenser or back to the Power Plant system.

Gas Cooler Water Treatment: This water treatment system is to prevent scale from forming in the boiler tubes; to prevent corrosion of the boiler pressure parts; and also to keep purity of the steam. This boiler water treatment is a low pH coordinated phosphate treatment. The chemicals used are tri-sodium phosphate (Na_3PO_4) and di-sodium phosphate (Na_2HPO_4). These chemicals are fed into the boiler drum at a ratio of Na_3PO_4:Na_2HPO_4 = 9.1 to obtain a control limit of 5 to 15 ppm of PO_4 with pH value of 9.7 to 10.2. Also added to this chemical treatment to prevent any oxygen corrosion is sodium sulfite, Na_2SO_3. This is controlled at 2 to 4 ppm. The dissolved solids in these boilers are always low because of the automatic blowdown system, which maintains the drum level when gas coolers are in the sparging condition. A small amount of filming amines is injected into the condensate system to prevent corrosion. These filming amines form a protective film on all metal surfaces.

Sootblowing: Each gas cooler is equipped with its own sootblower system. The function of the sootblower is to remove dust and any converter ash from the gas side surfaces of the gas cooler. These sootblowers use 210 psig. air to remove the undesirable accumulations. If the sootblowers are not operated regularly, the accumulation will continue to build up until it will lower the heat transfer of the gas cooler. Each gas cooler has eight long-retract sootblowers and six wall deslagers. The long retract sootblowers are arranged to clean all the pendant tubes. The wall deslagers extend only a short distance into the gas cooler, just far enough to clean the side wall tubes. The dust is removed from

the bottom of the gas cooler by a screw conveyor. This screw conveyor is automatically started and stopped by a timer relay. The sootblower system for each converter gas cooler is provided with an automatic sequence controller and interlock system. This controller is located in the gas cooler control room. Only one sootblower system can be operated at a time. Each system has provisions for automatic (sequential) operation of the sootblowers, for manual operation of any one sootblower, and for system monitoring from the control panel. A separate air system is provided to supply seal air to the sootblower wall boxes. This system takes air from the Plant 15 psig air header and reduces the pressure to 3 psig before it enters the sootblower wall box seals. This air is provided to prevent converter gas cooler gas-side pressure from blowing hot gas out and around the sootblower lances and to cool the lances when they are in the at-rest position.

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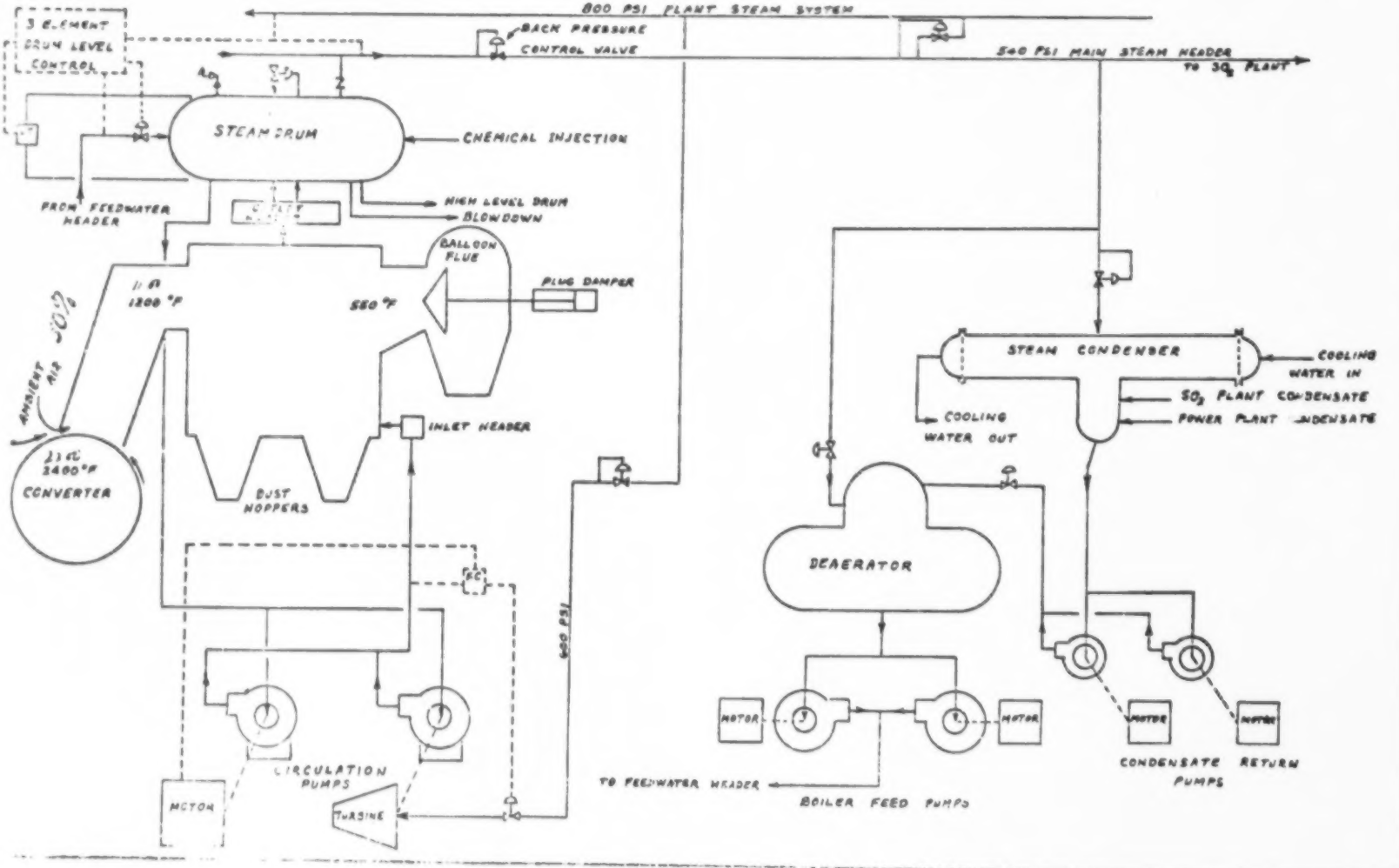
800 PSI PLANT STEAM SYSTEM
3 ELEMENT DRUM LEVEL CONTROL
BACK PRESSURE CONTROL VALVE
540 PSI MAIN STEAM HEADER
TO SO_2 PLANT
STEAM DRUM
CHEMICAL INJECTION
FROM FEEDWATER HEADER
HIGH LEVEL DRUM BLOWDOWN
BALLOON FLUE
PLUG DAMPER
1200 °F
560 °F
AMBIENT AIR 70°F
INLET HEADER
2400°F
CONVERTER
DUST HOPPERS
STEAM CONDENSER
COOLING WATER IN
SO_2 PLANT CONDENSATE
POWER PLANT CONDENSATE
COOLING WATER OUT
DEAERATOR
600 PSI
MOTOR
CIRCULATION PUMPS
TURBINE
TO FEEDWATER HEADER
BOILER FEED PUMPS
CONDENSATE RETURN PUMPS